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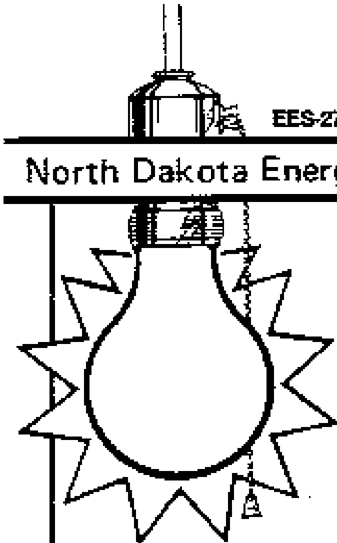

THE ENERGY-EFFICIENT CONSTRUCTION MANUAL: A Handbook for Builders and Developers

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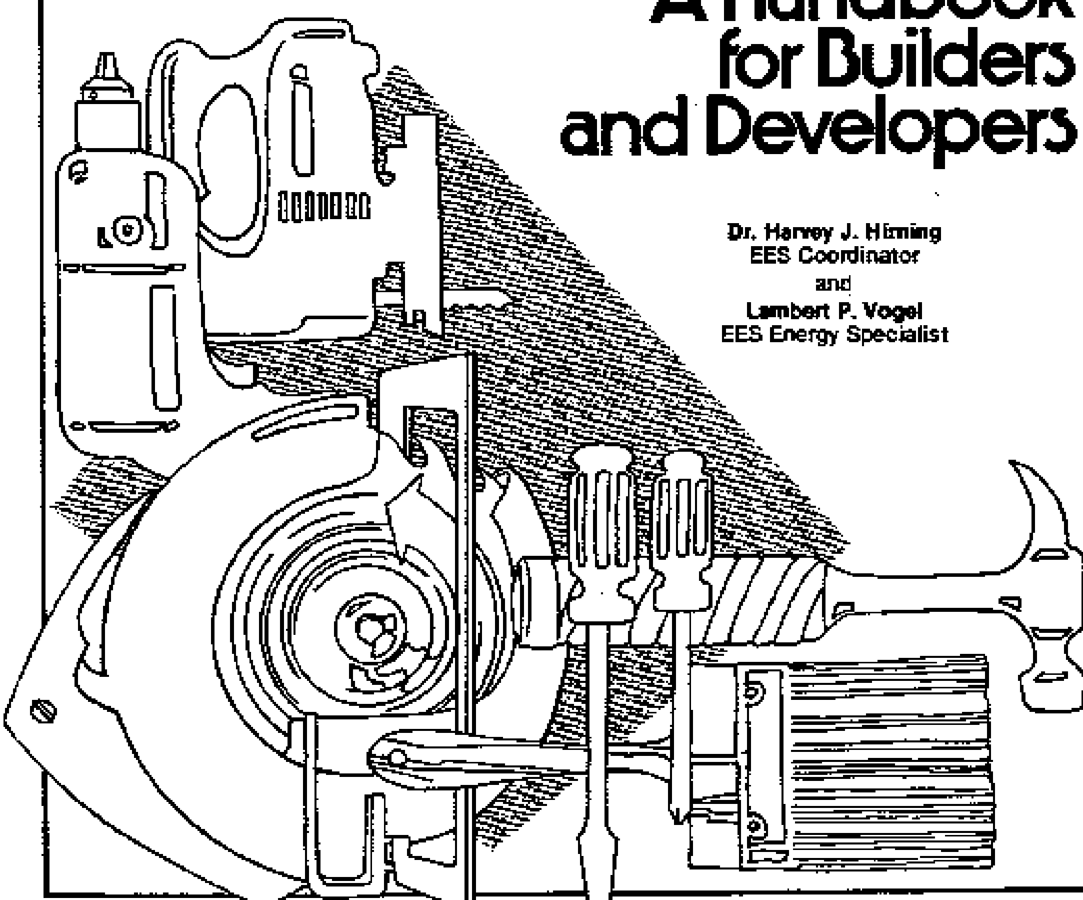

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Introduction

Superinsulated housing isn't new. In 1976, the University of Illinois Small Homes Council published a circular on the Lo-Cal House. The report was a computer study of the energy needs of a home using sizable amounts of insulation and air tightness quite different from that of houses built to comply with then-current building codes.

Because of the rapidly climbing energy costs of the '70s and the extremely cold climate (11,000 Degree-Days) of their Prairie Provines, Canadians quickly experimented with this type of construction. Much of the early superinsulation research was done at the University of Saskatchewan. One of the earliest "how-to" books on the subject was "Housing—A Prairie Approach" prepared by the university's mechanical engineering department and the provincial division of the Building Research Council.

Since this beginning some 10 years ago, hundreds of homes have used some or all of the concepts first outlined by Illinois. While some early mistakes were made, refinements in both techniques and equipment, as well as the advent of new products, have made this construction style one of the most promising of the energy conservation programs.

The first sections of this manual deal with the theory, terminology, and general information available about energy efficiency in the building environment. The second deals with residential considerations like single-family detached and multifamily structures. The appendix holds tables and other information that will allow you to utilize these ideas.

Macro-Climate

A region's general conditions make up its "macroclimate." Temperature in degree-days, wind direction and speed, solar insolation, percentage of possible sun, latitude, altitude, design temperature and moisture concerns (humidity, average raintall, snow load and frost penetration depth) are the major macro-climatic conditions.

Temperature

Temperature is the major determinant of a building's energy consumption. The temperature loads on buildings are indicated by the number of degree-days (DDs), both heating and cooling, and the design temperature.

Heating DDs are used to determine the seasonal heating load in an average year. The design temperature indicates the load's severity during the more extreme times of the year. (Design temperature = that temperature exceeded only 2.5 percent of the time.)

The DDs and winter design temperatures for North Dakota are in Appendix A. We've also provided a macro-climate worksheet, so you can compile all relevant data for your location in one easy-to-use chart.

If your location isn't listed, extrapolate from available sites and your own knowledge of your local climate. A sheet using data from Fargo, North Dakota, will be the basis for all examples in this manual.

Wind

Knowing about wind speed and prevailing direction can be useful in three ways: optimizing natural ventilation and cooling, minimizing winter heat loads, and determining the feasibility of wind electrical generation.

To optimize summer cooling, place ventilation openings to allow circulation when the cooling wind is from the prevailing direction. To minimize heat loads, it's best to locate windows and doors where they'll be protected from the prevailing winter winds.

If the two options conflict, emphasize the consideration creating the greatest energy load whether heating or cooling. In most of our region, heat load reduction is a more pressing concern.

Solar Insolation and Percent of Possible Sunshine

Energy-efficient structures are the ideal candidates for passive solar techniques.

The information you will want is solar insolation (amount of solar energy) and percentage of possible sunlight. Values are for these items are given in Appendix A.

Worksheet #1

Macro-Climate Design Chart

Project Location:
Latitude:
Altitude:

Design Temperature:
Frost Depth:

Month	Temperature			Normal Degree Days Base 65°F		Water Equivalent Average	Wind		% of Possible Sun	Mean Number of Days			Clear Day Insolation*
	Daily Maximum	Daily Minimum	Monthly Average	Heating	Cooling		Mean Speed	Prevailing Direction		Clear	Cloudy	Partly Cloudy	
Jan.													
Feb.													
March													
April													
May													
June													
July													
Aug.													
Sept.													
Oct.													
Nov.													
Dec.													
Average													

*on vertical surface

Macro-Climate Design Chart

Project Location: **Fargo, ND**
Latitude: **46°54'**
Altitude: **896'**

Design Temperature: **−22**
Frost Depth: **70"**

Month	Temperature			Normal Degree Days Base 65°F		Water Equivalent Average	Wind		% of Possible Sun	Mean Number of Days			Clear Day Insolation*
	Daily Maximum	Daily Minimum	Monthly Average	Heating	Cooling		Mean Speed	Prevailing Direction		Clear	Cloudy	Partly Cloudy	
Jan.	15.4	-3.6	5.9	1832	0	.50	12.9	SSE	51	6	8	17	873
Feb.	20.6	.8	10.7	1520	0	.44	12.8	N	57	6	7	15	1,184
March	33.5	14.9	24.2	1265	0	.83	13.4	N	58	5	9	17	1,380
April	52.6	31.9	42.3	681	0	2.08	14.4	N	57	6	9	15	1,312
May	66.8	42.3	54.6	334	11	2.29	13.4	N	58	7	10	14	1,227
June	75.9	53.4	64.7	97	88	3.20	12.0	SSE	60	6	11	13	1,161
July	82.8	58.6	70.7	13	190	3.16	10.8	S	71	11	13	7	1,304
Aug.	81.6	56.8	69.2	33	163	2.85	11.3	SSE	68	11	12	8	1,422
Sept.	69.6	46.2	57.9	234	21	1.84	12.3	SSE	60	9	9	12	1,426
Oct.	58.4	35.5	47.0	558	0	1.09	12.9	SSE	56	9	8	14	1,324
Nov.	37.2	20.0	28.6	1092	0	.72	13.2	S	40	5	7	18	902
Dec.	21.9	4.1	13.0	1612	0	.62	12.5	S	43	6	8	17	752
Average	51.4	30.1	40.8	9271	473	19.62	12.6	N	58	87	111	167	14,267

*on vertical surface

Latitude and Altitude

Because it makes winter solar performance vary, latitude must be included. And, because it determines sun angles throughout the year, it's a necessity in daylighting and shading analysis.

Altitude affects air clarity and density. Clarity is usually higher in high locations, leading to solar gain increases. High altitude's lower air density lowers the heating load due to infiltration.

Moisture

Moisture concerns are a mixed bag. Some are structural safety concerns, such as frost penetration depths and snow loads. Values for these are usually code-defined. On the other hand, average rainfall and relative humidity affect drainage problems, comfort levels, possible material selection and construction techniques. We'll discuss these matters as needed.

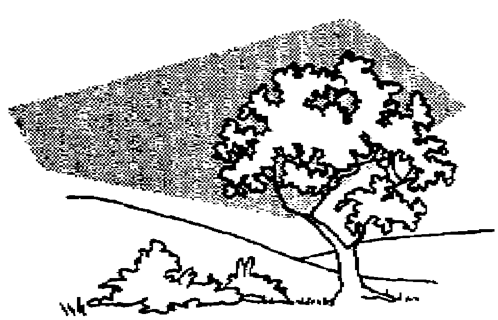
Micro-Climate

"Micro-climate" describes site-specific conditions, such as slope, vegetation, air movement and shading.

A southern slope impact moves the micro-climate hundreds of miles south. Likewise, a northern slope shifts it in a northerly direction.

By changing prevailing direction and velocity, slopes or hills can also influence wind direction and speed. Hills may funnel the wind, increasing average velocities, or break it, decreasing them. Slope also influences air movement by focussing cold air. Mountain valleys, for example, have fog and frost conditions not found farther up the slope.

Site vegetation is a double-edged sword for the builder and developer. While it can provide needed summer shading and cooling capacity, as well as breaking winter winds, it's just as likely to shade and funnel winter winds. The builder should carefully base decisions for either removing or planting vegetation on its impact on a proposed structure. For example, will a structure shade or influence wind patterns? And, although few conflicts between sun-tempered structure owners and their neighbors have occurred, it's probably due more to the scarcity of such buildings rather than to great planning. Potential development consideration is important.



Site Characteristics

Two site characteristics should be considered. Both earth sheltering and building orientation create opportunities for energy conservation.

Orientation is a structure's site placement. Orient structures to allow exterior areas to be used. Generally speaking, outdoor areas will be used more often if they're either south or east of the structure, as comfort is available during a greater part of the year on these two sides. Northern exterior spaces get the lowest use because of their low comfort levels most of the year.

If heating is your main concern, orient your structure to use solar gain. Conversely, if you're interested in cooling, orient the building to exclude the sun. However, almost all structure orientations are adequate as long as window and use-area placements are sensitive to needs. Exact placement is less important than the proper planning of interior use and window openings.

Heat Transfer

If you're going to build an energy-efficient structure, you should understand heat transfer. The following section will help you understand structural energy flow.

There are four modes of heat transfer that affect human comfort: conduction, convection, radiation, and evaporation.

Conduction

The heat flow from molecule to molecule within a structure is conduction. You can see the process act on a skillet handle when you hold the skillet over a burner. As the skillet warms, the heat is conducted, molecule by molecule, to the handle. Pot holders are family monuments to conductive heat transfer's effectiveness.

The ability to conduct heat varies from material to material. Those that readily conduct heat are called conductors, while those that resist are called insulators.

While working with building materials, two terms are used when calculating heat loss. The first, U-value, refers to a material's conductivity. However, since U-values are hard to manipulate when a variety of materials is used in combination, R-values are often used instead. (R-value = 1/U-value)

Because R-value is additive, computing structural heat loss when many building materials are present is easier. We've listed both R- and U-values in Appendix B.

Convection

Both forced and natural convection happen because fluids settle when cooled and rise when heated. As examples of natural convection, watch chimney smoke rise and feel cool air on a window fall.

Forced convection is used in most central heating systems. In these systems, a fan or pump moves the fluid to the end use point, usually at floor level, where it's allowed to rise and heat the room. As the air cools, it falls, is recovered through a cold return and recirculated through the system.

Radiation

Radiation is the transfer of heat by electromagnetic waves. Radiation heat transfer is a function of the temperature difference of the objects involved.

Solar energy is the best example of radiation. A person sitting in direct sunlight, in still air at 60 degrees Fahrenheit, will feel warm. Removing the sunlight will lead to a feeling of being cool even if the temperature remains the same.

The massive flow of radiation to the earth shows us the effectiveness of this type of heat transfer. One of the most desirable effects of radiant energy is its ability to move from warm to cold objects without heating the air in between.

Evaporation

Evaporation is the process of vaporizing a liquid (water) and transferring the heat to the environment.

Humidity levels influence evaporation; during high humidity periods, there's little evaporation heat transfer. However, if environmental humidity levels are low, evaporation heat transfer is rapid. Energy-efficient structures maintain higher humidity levels during the winter, reducing their occupants' evaporation heat loss to the environment and leading to a higher comfort level.

Heat transfer depends on physical properties. The terms to understand are mass, heat, BTU, and temperature.

Mass

Mass is the amount of material in an object in pounds. It has an impact on the thermal cycling of buildings (daily highs and lows) by serving as a damper. It also serves as a storage medium for solar energy, allowing limited carryover from sunny to cloudy days.

Heat and BTUs

Heat is measured in British Thermal Units (BTUs) or calories. One BTU will raise the temperature of one pound of water one degree Fahrenheit. (The heat generated by a kitchen match roughly equals one BTU.) One Calorie will raise the temperature of one liter of water one degree Celsius. (A Calorie equals 3.97 BTUs).

Temperature

Temperature differs from heat in that it is a measure of heat concentration in a mass.

For example, we can add the same quantity of energy/heat, 10 BTUs, to two water containers, one holding one pound of water, the other 10 pounds.

The quality, or concentration of energy/temperature, of the two containers changes quite differently. One container's temperature will rise 10 degrees Fahrenheit while the other's will only rise one.

Heat Loss

The following heat loss procedure was borrowed from the Passive Solar Design Handbook, Volume 2 (available from the National Technical Information Service (NTIS), No. DOE/CS-0127/2).

The following calculations may be used for all structures with mainly heating or cooling loads. For commercial or industrial construction projects, which have large internal loads and special ventilation requirements in the energy load, follow ASHRAE[1] procedures. Some R-values are listed in Appendix B.

Walls

$$L_w = 24 \times \frac{\text{wall area}}{\text{R-value of wall}}$$

Where L_w = heat loss through the wall in BTU/Degree Day (DD)

Where wall area = (perimeter) x (ceiling height) − (window area) − (door area)

Windows

$$L_g = 25 \times \frac{\text{window area}}{\text{number of glazings}}$$

Where L_g = heat loss through the glazings in BTU/Degree Day

Where window area = net glazed area of all windows

Perimeter (slab-on-grade)

$$L_p = 100 \times \frac{\text{length of perimeter of foundation}}{\text{R-value of perimeter of insulation} + 5}$$

Where L_p = heat loss through perimeter in BTU/Degree Day

Floor (over vented crawl space)

$$L_f = 24 \times \frac{\text{area of ground floor}}{\text{R-value of ceiling}}$$

Where L_f = heat loss through the floor in BTU/Degree Day

Basement Walls

$$L_b = 32 \times \text{length of wall} \times \left[\frac{\text{height below grade}}{\text{R-value of wall} + 8} + \frac{\text{height above ground}}{\text{R-value of wall}}\right]$$

Normally, only one of L_p, L_f, and L_b will apply.

Roof

$$L_r = 24 \times \frac{\text{roof area}}{\text{R-value of ceiling}}$$

Where L_r = heat loss through the roof in BTU/Degree Day

Doors

$$L_d = 24 \times \frac{\text{door area}}{\text{R-value of doors}}$$

Where L_d = heat loss through the doors in BTU/Degree Day

Infiltration

L_i = (0.432) x (average air changes/hr.) x (ADR) x ceiling height) x (combined area of all floors)

Where L_i = heat loss through infiltration in BTU/Degree Day

Where ADR = air density ratio determined by using Figure 1.

BLC

When you've calculated all the appropriate figures for the structure you're studying, add them together to arrive at the Building Load Coefficient (BLC).

$$BLC = L_w + L_g + L_b + L_r + L_d + L_i$$

[1]ASHRAE: The American Society of Heating, Refrigeration and Air Conditioning Engineers.

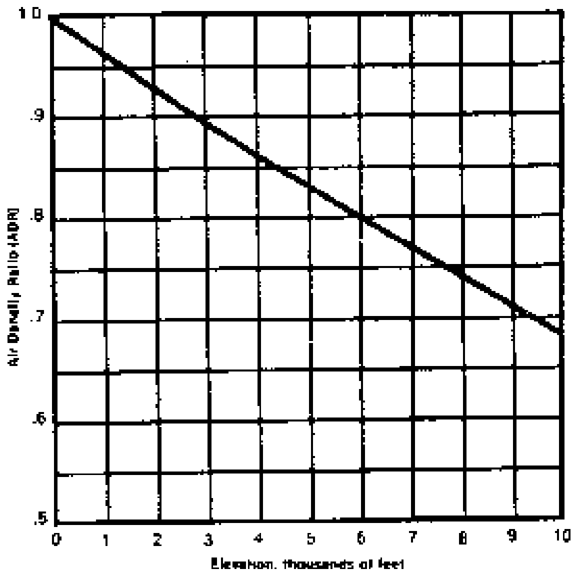


Figure 1. The Air Density Ratio (ADR) for different elevations.
Source: J. Douglas Balcomb et al. Passive Solar Design Handbook Vol. 2: Passive Solar Design Analysis: (Los Alamos' Scientific Laboratory: U.S. Department of Energy), 1980, p. 35.

Note: If there's more than one building component configuration (different R-value, different number of glazings, etc.), calculate a separate number for each configuration.

Example

Consider a 24 foot by 40 foot house with full basement. Component R-values are: walls (R-19); ceiling (R-38); double-glazed windows, with 100 square feet of area; doors with a total area of 38 square feet (R-3.5); basement with two feet above grade and six feet below grade insulation (R-5); infiltration equals .65 air changes per hour. The house is in Fargo, North Dakota, at an elevation of 890 feet.

$$L_w = 24 \times \frac{(128) \times (8) - (100) - (38)}{19} = 1{,}119 \text{ BTU/DD}$$

$$L_g = 26 \times \frac{100}{2} = 1{,}300 \text{ BTU/DD}$$

$$L_b = 32 \times 128 \times \left[\frac{5}{13} + \frac{2}{5}\right] = 3{,}529 \text{ BTU/DD}$$

$$L_r = 24 \times \frac{960}{38} = 606 \text{ BTU/DD}$$

$$L_d = 24 \times \frac{38}{3.5} = 260 \text{ BTU/DD}$$

$$L_i = (0.432) \times (.65) \times (.97) \times (8) \times (1{,}920) = 4{,}184 \text{ BTU/DD}$$

$$BLC = 1{,}119 + 1{,}300 + 3{,}539 + 606 + 260 + 4{,}184 = 10{,}998 \text{ BTU/DD}$$

The BLC is useful in four ways:

1. **To size the heating system.**

$$\frac{BLC \times (70^\circ F - \text{design temperature})}{24}$$

= heating system size (delivered to space) in BTUs

$$\frac{10{,}998 \times (70^\circ F - (-22))}{24} = 42{,}125 \text{ BTU/hr delivered to space}$$

2. **To compare differing structures' energy loads.**

$$\frac{BLC}{ft^2 \text{ of living space}} = \text{BTU/DD/ft}^2 \text{ of living space}$$

$$\frac{10{,}998}{1{,}920 \text{ ft}^2} = 5.73 \text{ BTU/DD/ft}^2$$

(This figure's useful as a marketing tool; the lower the figure, the better.)

3. **To analyze where opportunities for further conservation exist.**

To do this analysis, you need to break down the heat loss components into percentages of the BLC.

$$\frac{BLC}{BLC} = \frac{1{,}119}{10{,}998} + \frac{1{,}300}{10{,}998} + \frac{3{,}529}{10{,}998} + \frac{606}{10{,}998} + \frac{4{,}284}{10{,}998} \text{; or}$$

100% = 10.2% + 11.8% + 32.1% + 5.5% + 2.4% + 38%

This percentage breakdown allows you to easily see which components are losing the most energy and thus allows you to look at alternative methods and materials that can have the greatest impact on savings.

In the example, it's obvious the basement walls and infiltration are the real problems. As an experiment, let's increase the basement insulation to R-17 and reduce air infiltration to 0.1 air changes per hour of uncontrolled infiltration, plus a resultant 0.1 air changes per hour by ventilating 0.5 air changes per hour through an 80 percent efficient air-to-air heat exchanger. (This gives us a total 0.2 air changes per hour.)

$$BLC = 1{,}119 + 1{,}300 + 1{,}465 + 606 + 260 + 1{,}287 = 6{,}037 \text{ BTU/DD}$$

By attending to these two areas, we've reduced the heating load 45 percent. The value of this type of analysis is obvious; it allows you to target those areas where maximum energy conservation impact's possible.

4. To calculate the yearly heating bill.

You can calculate the yearly heating bill for an average year by using the following formulas:

BLC x yearly degree-days = yearly heating load in BTUs

Multiply the yearly heating load by the appropriate conversion factor from Table 1.

Note: Some agencies use the Thermal Integrity Factor (TIF) to measure thermal performance. In section 2, we calculated the BTU/DD/ft^2. TIF uses the same units, but takes into account heat gains, such as solar gain through south windows and internal gain generated by occupants.

In homes built before 1960, the TIF averaged 12 BTU/DD/ft^2. After 1970, the TIF averaged between 7 and 9 BTU/DD/ft^2. A superinsulated home may have a TIF of about 1 BTU/DD/ft^2.

The TIF was developed by the Mid-American Solar Energy Complex (MASEC), and a number of superinsulated homes use it as a measure of thermal performance.

If you calculate the heat losses of the structures you're building, you'll get a much better idea of what goes on inside a home or office when it loses heat.

The calculations are relatively simple for most structures, and we urge you to become familiar with them so you can maximize energy efficiency at a minimum cost. You can duplicate Worksheet 2 for use in your day-to-day work.

Common R-values are in Appendix B.

Table 1 Heating Cost Conversion Factors

Natural Gas	$\frac{\$ \text{ Cost Per MCF}}{1{,}000{,}000 \times \text{Furnace Efficiency}}$
Oil	$\frac{\$ \text{ Cost Per Gallon of Oil}}{138{,}680 \times \text{Furnace Efficiency}}$
Electricity	$\frac{\$ \text{ Cost Per KWH}}{3413}$ (100% Efficiency assumed)
Coal (Lignite)	$\frac{\$ \text{ Cost Per Short Ton}}{14{,}000{,}000 \times \text{Furnace Efficiency}}$
Wood (hardwood)	$\frac{\$ \text{ Cost Per Cord}}{18{,}000{,}000 \times \text{Furnace Efficiency}}$

Worksheet #2

HEAT LOSS WORKSHEET

	OPTION 1		OPTION 2		OPTION 3	
	BTU/DD (From Formulas)	% of BLC	BTU/DD (From Formulas)	% of BLC	BTU/DD (From Formulas)	% of BLC
L_w	1.					
	2.					
	3.					
L_g	1.					
	2.					
	3.					
L_p	1.					
	2.					
L_f	1.					
	2.					
L_b	1.					
	2.					
L_r	1.					
	2.					
L_d	1.					
	2.					
L_i	1.					
Total (BLC)						

$$L_w = 24 \times \frac{\text{wall area}}{\text{R-value of wall}}$$

$$L_g = 28 \times \frac{\text{window area}}{\text{number of glazings}}$$

$$L_p = 100 \times \frac{\text{length of foundation perimeter}}{\text{R-value of perimeter insulation} + 5}$$

$$L_f = 24 \times \frac{\text{ground floor area}}{\text{R-value of floor}}$$

$$L_b = 32 \times P \times \left[\frac{Hbg}{R+8} + \frac{Hag}{R} \right]$$

$$L_r = 24 \times \frac{\text{roof area}}{\text{R-value of ceiling}}$$

$$L_d = 24 \times \frac{\text{door area}}{\text{R-value of doors}}$$

L_i = (.432) × (average air changes per hour) × (ADR) × (ceiling height) × (combined area of all floors)

BLC =

Heat System Size

$$\text{BLC} \times \frac{(70° - (\text{Design Temperature}))}{24} = \text{Heat system size (BTU/hr.)}$$

_____ × (70°-( )) ÷ 24 = _____ BTU/hr.

_____ × (70°-( )) ÷ 24 = _____ BTU/hr.

_____ × (70°-( )) ÷ 24 = _____ BTU/hr.

Yearly Heating Cost

BLC × Yearly Degree-Days × Heating Cost Conversion Factor = Yearly Heating Cost

_____ × _____ × _____ = $_____

_____ × _____ × _____ = $_____

_____ × _____ × _____ = $_____

Heating Cost Conversion Factors

Natural Gas $$\frac{\$ \text{ Cost Per MCF}}{1{,}000{,}000 \times \text{Furnace Efficiency}}$$

Oil $$\frac{\$ \text{ Cost Per Gallon of Oil}}{138{,}680 \times \text{Furnace Efficiency}}$$

Electricity $$\frac{\$ \text{ Cost Per KWH}}{3413}$$

Propane $$\frac{\$ \text{ Cost Per Gallon}}{91{,}600 \times \text{Furnace Efficiency}}$$

Example Worksheet #2

HEAT LOSS WORKSHEET

	OPTION 1		OPTION 2		OPTION 3	
	BTU/DD (From Formulas)	% of BLC	BTU/DD (From Formulas)	% of BLC	BTU/DD (From Formulas)	% of BLC
L_w	1. 1119	10.2%	1119	18.5%	680	13.7%
	2.					
	3.					
L_g	1. 1300	11.8%	1300	21.5%	867	17.4%
	2.					
	3.					
L_p	1.					
	2.					
L_f	1.					
	2.					
L_b	1. 3529	32.1%	1465	24.3%	1465	29.4%
	2.					
L_a	1. 606	5.5%	606	10%	419	8.4%
	2.					
L_d	1. 260	2.4%	260	4.3%	260	5.2%
	2.					
L_i	1. 4184	38%	1287	21.3%	1287	25.9%
Total (BLC)	10,998		6037		4978	

$$L_w = 24 \times \frac{\text{wall area}}{\text{R-value of wall}}$$

$$L_g = 26 \times \frac{\text{window area}}{\text{number of glazings}}$$

$$L_p = 100 \times \frac{\text{length of foundation perimeter}}{\text{R-value of perimeter insulation} + 5}$$

$$L_f = 24 \times \frac{\text{ground floor area}}{\text{R-value of floor}}$$

$$L_b = 32 \times P \times \left[\frac{Hbg}{R+8} + \frac{Hag}{R}\right]$$

$$L_r = 24 \times \frac{\text{roof area}}{\text{R-value of ceiling}}$$

$$L_d = 24 \times \frac{\text{door area}}{\text{R-value of doors}}$$

L_i = (.432) × (average air changes per hour) × (ACH) × (ceiling height) × (combined area of all floors)

BLC = (10,998) (6,037) (4,978)

Heat System Size

$$\frac{\text{BLC} \times (70° - (\text{Design Temperature}))}{24} = \text{Heat system size (BTU/hr.)}$$

10,998 × (70° -(-22)) ÷ 24 = 42,159 BTU/hr.

6,037 × (70° -(-22)) ÷ 24 = 23,142 BTU/hr.

4,978 × (70° -(-22)) ÷ 24 = 19,082 BTU/hr.

Yearly Heating Cost

BLC × Yearly Degree-Days × Heating Cost Conversion Factor = Yearly Heating Cost

10,998 × 9,271 × .035/3413 = $1,046
6,037 × 9,271 × .035/3413 = $ 574
4,978 × 9,271 × .035/3413 = $ 473

Design Concerns

The five crucial components you must consider in energy-efficient residence design are: adequate insulation; a continuous vapor barrier; an air-to-air heat exchanger; energy-conserving devices and appliances; and attention to details.

Once you've ensured these five components, the following design considerations will further reduce energy needs. Design phase care is a great way to reduce energy consumption.

First, situate the home with its long axis east and west. Next, design often-used spaces, such as kitchens, living and dining rooms, with open plans that allow heat and light sharing.

Close or isolate occasionally used rooms so they're heated only when used. Place less-used rooms on the north. Garages, laundries, and storage, stairways, hallways, and workshops make fine buffers.

Place rooms according to their time of use. Bedrooms and kitchens located to receive morning light are often desirable. Put daytime living spaces on the south, where heat and light are easily available.

Balance openings for summer ventilation and isolate or vent heat-generating appliances for summer cooling.

Cluster plumbing fixtures near the water heater to minimize piping runs and heat loss. Concentrate windows on the structure's south side.

Finally, if you have a masonry chimney of any kind, locate it within the building envelope so it will serve as a thermal mass. Remember, a chimney, in addition to heating, also serves as an excellent cold surface when it's not in use.

The Building Envelope

Energy-efficient wall materials are traditional. However, the ways they're used may be new to the builder.

In walls, commonly used materials include two-by-fours or two-by-sixes. However, if you want a wall thicker than 5½ inches, you'll find it easier and more cost-effective to use a double two-by four wall the thickness you desire. In the techniques section, we'll discuss the way you can assemble these materials on-site.

Flooring materials are also traditional. However, it's imperative to compare the costs of different materials and the test results that may allow substitutions.

Any floor above a crawl space or basement should (unless the foundation or basement insulation is adequate) be insulated.

Basements are part of 90 percent of all the homes in North Dakota. The key material to consider is appropriate basement insulation. We'll discuss insulation materials later.

Adequately insulated roofs or ceilings present some common problems. In truss-type roofing systems, for example, it's easy to provide adequate insulation depths, except along the area directely above the exterior walls.

You'll need room for full insulation depth directly above the exterior walls, plus enough clearance for ventilation. Two inches of clear space above the insulation will provide adequate ventilation.

If you want a cathedral or other combined roof-ceiling, it's difficult to get adequate insulation R-value using standard construction lumber. Even if two-by-twelves are used, it's still possible to use only nine inches of batt insulation and still provide ventilation.

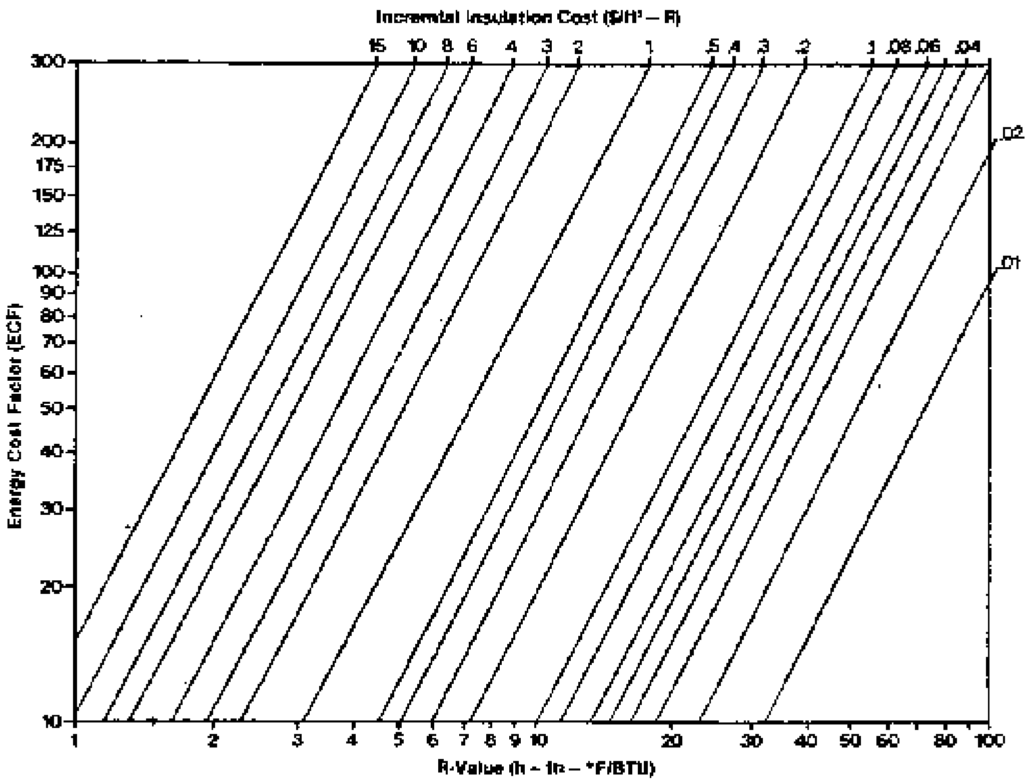
A 20 R-value is simply inadequate for ceiling areas. The best options are plywood-type roof beams, with enough depth to allow insulation R-values to increase to the R-50 or R-60 range or a board-type insulation, installed either over or under standard framing materials. The option you choose will depend on the comparative costs of the two systems at the time you're building.

Energy Cost Factor (ECF) and Insulation Levels

It's apparent that a way to determine adequate insulation values must be used. We feel the generalized insluation curve (Figure 2) is a good way to decide what insulating values are best. The procedure for using this graph is:

Step 1: Calculate Energy Cost Factor (ECF), using the following formula: ECF = $(7.03 \times 10^{-3}) \times$ (cost of energy (\$/KWH)) $\times$ (Degree-Days) $\times$ (discount factor), where discount factor = mortgage period (years) $\div$ 1.1

Figure 2.



Example: Calculate the ECF for 9,200 DDs for a 30-year mortgage. Energy cost of $.035 per KWH.
ECF = (7.03 × 10⁻³ × ($.035/KWH) × (-9,200 DD) × (30/1.1)is ECF = 61.7.

Step 2: Plot a horizontal line from the ECF to the increment insulating costs curve and down to the R-value.

Example: Cellulose insulation at $.02/ft²/R in a ceiling. Optimum R-value is R-56.

You'll find it useful in your analysis to fill out Worksheet 3 and keep it current. By having up-to-date cost data on insulation (both material and labor), you'll be able to use the graph to easily calculate optimum insulation values. Because the formula allows for different degree-day uses, it's easy to adapt it to your individual situation.

Worksheet #3

Project Number:	Functional Element:	Sheet #__ of __
Design Description:		
Location:		Date:
Calculated by:		

ITEM	DESCRIPTION	COST UNIT	COST				AMOUNT	TOTAL COST	NOTES
			MAT.	LABOR	O&P	TOTAL			

MATERIALS

Insulation

Reducing conductive heat loss through the building envelope is insulation's main function. Thus, the primary concerns with insulation are R-values and costs. There are many insulating materials on today's market, including cellulose, fiberglass, expanded and extruded polystyrene and urethane.

Cellulose

Cellulose is a loose-fill insulation material, most commonly used in ceilings. While its R-values may vary depending on application, a value of 3.5 per inch can be assumed.

Cellulose has a tendency to settle, and this will create a gradual lowering of the R-values over time. If it's applied in walls, up to one-third settling may occur, leaving an uninsulated wall area with massive heat loss.

If you apply cellulose to a wall, maintaining a density of 2.5 to 3 pounds per cubic foot will help avoid settling problems.

When properly used, cellulose is a superb insulation. Little energy is invested in the manufacturing process, so the long-term cost outlook is better than it is for other materials with high energy inputs. It needs a vapor barrier, has no known major health hazards for applicators or residents, and can be reapplied if settling has had a significant impact on the R-value.

Instances of non fire-retardant cellulose have appeared. To ensure fire safety, it's always a good idea to try a burn test on any cellulose. Simply hold a handful next to a flame; if it burns, reject it. All cellulose insulation sold should have a label indicating that it meets HUD standards for fire resistance and non-corrosiveness.

Fiberglass

When applied as batts or rolls, fiberglass has an approximate R-value of 3.1 per inch. Coming in 16-, 24-, and 48-inch widths (the last is harder to find), it's the predominant insulating material in American building construction.

Fiberglass needs a vapor barrier and, for all practical purposes, is fireproof. However, it does pose a hazard to the applicator's lungs and skin. Take special care when applying it. (We recommend wearing a mask and full body covering.)

While fiberglass costs run slightly higher than cellulose costs, there's no better insulation for standard framed construction walls and floors. Construction crews are familiar with its application, making its use in superinsulated construction easy.

Incidently, the Kraft or aluminum facing on fiberglass batts or rolls is an ineffective vapor barrier unless it's sealed. Also, the adhesives used in kraft and foil barriers may be flammable and should be covered after they're installed.

Expanded Polystyrene (Beadboard)

Made of beads fused with heat and pressure, beadboard is rated at R-4 per inch. As a petroleum product, it's directly affected by energy cost escalations. Coming in 4-foot by 8-foot sheets of varying thickness, it's easily cut and can be used to insulate basement interiors, shutters, and masonry walls.

However, it does have several disadvantages when used as insulation. If exposed to sun, it degrades quickly and must be coverd when used in exposed positions. It produces dangerous fumes when burning, so it must have fire protection, such as sheetrock, added for interior applications.

It will also take on moisture, reducing its insulating value, so it needs a vapor barrier.

When applying any petroleum-based board insulation, make a compatability test between the insulation and the adhesive. Some adhesives will eat into the insulation and fail to bond properly. Testing compatability is essential for a proper bond.

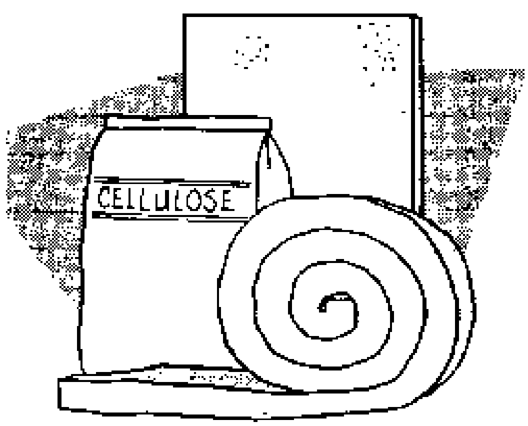
Extruded Polystyrene

Styrofoam is the registered brand name for an extruded polystyrene insulation board manufactured by Dow Chemical Company. Three other companies now produce this type of insulation.

Because it's extruded, it's highly impervious to moisture penetration, making it quite desirable for subgrade exterior insulation applications where moisture may be present in concentrated amounts.

Tongue-and-groove configurations make an excellent air infiltration barrier when used as an exterior sheathing. It has an R-value of 5 per inch.

Extruded polystyrene must be covered to protect it from the sun. It also burns readily in vertical applications, forming dangerous smoke and fumes. In interior applications, it must always be protected by a fire-rated covering. Costs will vary.



Urethane and Isocyanurate

Urethane and isocyancurate insulations are available in sheet form for easy application. Their R-values are 7 per inch.

These materials, often faced with aluminum foil, are commonly used in new construction to bring a two-by-four stud wall up to R-19. However, there are several difficulties associated with these products that you should understand.

First, they're petroluem products, with associated cost problems.

Second, they're foamed with freon, which has a higher resistance to heat transfer than air until it begins to condense at −20 degrees Fahrenheit. Unless it's been totally sealed at all edges, freon migrates from the product. This means R-values decline with age in most applications.

Third, urethane and isocyanurate will take on moisture and shouldn't be used subgrade or without a good vapor barrier.

Finally, since it's highly combustible, urethane must be isolated from the living space by a fire barrier like sheetrock. While isocyanurate insulation has a much lower fire spread rating, it still should have fire protection.

Vapor Barriers

A vapor barrier impedes water vapor's passage from the interior space into the wall cavity and outside.

Interior moisture levels are usually high enough to create a large vapor pressure differential between exterior and interior air. If the barrier allows vapor to migrate through the building envelope, condensation is likely. This leads to rot problems, peeling paint, and reduced insulation effectiveness.

Vapor barrier integrity is one of the five cardinal points of building an energy-efficient structure. A high-quality vapor barrier also allows you to drastically cut infiltration heat losses.

Six-mil polyethylene film is the most common vapor barrier material. Two other recently developed products, RUFCO and TU-TUF, have also been successfully used.

Installing these products means close attention to detail. Recommended placement details and joint treatment are shown in the section on building details.

Available Kraft- or foil-faced insulations are inadequate vapor barriers unless they're sealed. Because sealing is difficult and time consuming, unbacked insulation covered with a polyethylene vapor barrier or equivalent is a good strategy. An air barrier sometimes used is a product known as TYVEK. This sheet material allows water vapor to pass through while restricting air movement. It's installed on the sheathing's exterior.

Windows and Doors

Building envelope openings have an effect on both heating and cooling loads. In most cases, while occupying less than 15 percent of the envelope area, they still constitute a major part of the energy load. A good rule-of-thumb for window area is between 8 and 10 percent of the floor area with the major percentage on the south side, enough area on the north side for visibility, and the remainder on the east and west sides.

The window units should be of good quality and well built with good durable weatherstripping. Double-glazed windows have become standard on conventional new homes. Triple- and quadruple-glazed windows have a better insulative quality compared to double-glazed windows, but probably more important provide a window system that will tolerate higher inside humidity without condensation. The air gaps in multiglazed windows should be greater than 3/8 inches to gain maximum benefit from the air space. Window systems with metal frames should include a thermal break.

In selecting the window system, the factors mentioned as well as costs will have to be analyzed.

Rather than making a blanket statement about how many glazings are needed, you must analyze the air gap situation and cost differences between integral window layers versus adding a storm window. Again, develop a window cost sheet, much like its insulation cost counterpart, that will let you compare options.

Doors are a double concern. They're a load source by both conduction and infiltration.

If you're installing a door, make sure it's insulated and high-quality weatherstripping is used. If all other design and construction measures are taken to ensure an extremely tight home (high-quality windows,

CAULKING MATERIALS

Type	Relative Cost	Durability	Installation	Comments
Oil or Resin Base	lowest	good	poor	Not for long-term caulking
Latex Base	low	good	fair	Some shrinkage
Butyl Rubber	low	good	fair	Not for moving joints
Polyvinyl Acetate	medium	good	fair	Shrinks and hardens
Neoprene Rubber	medium/high	good	good	Concrete walls/foundations
Silicone	high	good	good (not to concrete)	Remains flexible/not paintable
Polysulfide	high	needs primer	good	Can dry out
Polyurethane	high	good	good	
Hypalon	high	good	good	Not readily available
Polymeric Foam	high	good	good	For sill plates and large holes
Sub-floor Adhesives	medium	good	good	For poly vapor barriers
Acoustical Sealants	medium	good	good	For poly vapor barriers

WEATHERSTRIPPING MATERIALS

Adhesive-backed Foam	low	poor	easy	Best on doors
Hair/Felt	low	poor	easy	Will compact
Foam with wood backing	medium	fair	easy	For windows and doors
Door Sweeps	medium	fair	easy	May drag on carpet
Spring metal	high	excellent	easy	For windows and doors
Rolled Vinyl/Aluminum	high	fair	medium	For windows and doors
Door Shoes/Vinyl Bulb	high	excellent	difficult	For doors only

Source: Robert Argue, The Well Tempered House: Energy Efficient Building for Cold Climates; Renewable Energy in Canada, 1980, p. 31.

continuous vapor barrier, high-quality caulking and sealing), you may not need an air lock vestibule in new construction.

It appears occupant lifestyle may be the overriding concern when considering a vestibule. Door traffic is related to the number of occupants, their ages, and their lifestyles.

A family of six with four children under 12 may very well need a vestibule. An older family may not. A family that frequently entertains may need a vestibule, while one that doesn't entertain often, or invites few guests, probably won't. Once again, it's obvious blanket answers just won't work.

Building Techniques

There are four components to an energy efficient structure: high insulation levels; a continuous and carefully installed vapor barrier; an air-to-air heat exchanger; and energy-saving devices and appliances within the building. Careful attention to all four will allow you to maximize savings.

Ceilings

With the exception of the exterior wall line, where special framing may be needed to provide adequate depths, attics are large enough to insulate.

Install insulation stops to ensure adequate ventilation and prevent spillage into the soffits. Pay special attention to the attic access door. If it's inside the home, insulate and weatherstrip it well. Preferably, it should be located in a gable end when located outside. When outside access is provided, most access problems are solved.

Note: If you're going to use blown insulation, it's very important to ensure consistent depth. Place three or four strings across the attic space at the proper height to make a consistent application easier.

Cathedral Ceiling Insulation

Cathedral ceilings create special insulation problems. If fiberglass batts are installed in rafters, depths beyond nine inches are impossible. Since finished rafter systems can produce extra living space at a reasonable cost, and are often desirable from a consumer's standpoint, some means of dealing with them must be found.

Five ways of adding insulation are possible: applying strapping to the rafter's inner surface, allowing additional batt insulation; adding board insulation to the rafter's interior surface; using plywood beams to provide depth, and using a truss-type rafter. Insulation can also be installed on the exterior.

Ceiling Vapor Barriers

Including a continuous vapor barrier is a primary concern of the energy efficient builder or developer.

If you remove ceiling light fixtures and substitute lamps, wall mounts or other systems, you'll simplify the installation of your vapor barrier. However, if you plan to use ceiling fixtures, install vapor barrier pans (like the ones described in the single-stud wall vapor barrier discussion) around them.

Walls

Creating high (R-30 to R-50) wall insulation levels has special problems. The two techniques you can use are: single-stud walls with exterior board insulation and double-stud walls with standard batt insulation. While the cost of either is about the same, keep close track of prices regularly so you can use the most cost effective.

Single-Stud Walls

The maximum effective R-values for standard framed single-stud walls with exterior board insulation range from 30 to 35.

The first of the two exterior treatments involves attaching rigid expanded polystyrene boards to the wall's exterior with a special adhesive. A fiberglass-reinforced mastic layer is then attached to the boards. Next an exterior coat is trowelled on. Because the coat (available in a variety of textures and colors) replaces the siding, the economics are excellent.

The second treatment involves attaching extruded polystyrene, up to two inches thick, to the exterior, followed by standard siding. This system is useful for those who don't like a stucco-like finished appearance.

The advantages of building a single-stud wall include: standard techniques for the building crews; a minimal reduction of floor space; and an easier and less costly finishing of doors and windows.

The disadvantages, however, include: difficulty in ensuring a continuous vapor barrier; a limiting of siding options; the labor-intensive raising of two-by-six walls; and its use only up to R-35 insulation levels.

Vapor Barriers in Single-Stud Walls

A single-stud wall's greatest single difficulty is obtaining a continuous vapor barrier. The area of greatest concern is the electrical outlet.

It's a common practice to simply cut holes in the vapor barrier surrounding the outlets and attach the sheetrock. Although quick and easy, this practice negates many of the vapor barrier's benefits, since both air infiltration and vapor passage increase dramatically.

The best way to solve the problem is by putting polystyrene pans around the outlets and sealing the wire passage points with caulk. You can then fill the pans with insulation. Details of this technique can be found in the construction details section.

Double-Stud Walls

A builder or developer needs the double-stud system if structural walls are to be in the R-40 to R-50 range.

Whenever wall cavities will be more than 5½ inches deep, use the double-wall. Two-by-four and two-by-three lumber is usually cheaper than structural lumber in two-by-eight or larger sizes. Two-by-four and two-by-three walls are lighter and easier to raise.

Attach the vapor barrier to the outer side of the inner wall, removing the problem of subcontractors puncturing the barrier while working.

There are two ways to put up double-wall structures. Some recommend building both walls, attaching the vapor barrier, connecting the two walls with plywood at top and bottom and raising the wall as a unit. Others advocate framing the outside walls, installing the trusses and roofing system, sheathing the frame and then installing the inner walls with the vapor barrier attached.

Both systems provide the same finished product. By raising the walls separately, labor advantages are maintained and damage to the vapor barrier is less likely.

If the first technique is used, the sheathing is usually installed on the outside of the vapor barrier and the inside wall is the structural wall. This allows the outer wall to be cantilevered over the subflooring, reducing floor space loss and allowing a smoother transition to basement or foundation insulation.

Both systems have merit and should be considered before making a decision.

Among its advantages, the double-stud wall system accomodates R35+ insulation , makes it easy to provide a continous vapor barrier; minimizes wall erection labor, and has no siding limitations.

Among its disadvantages, it means an unfamiliar building technique for some crews, a possible reduction in floor space, and more difficult window and door finishing.

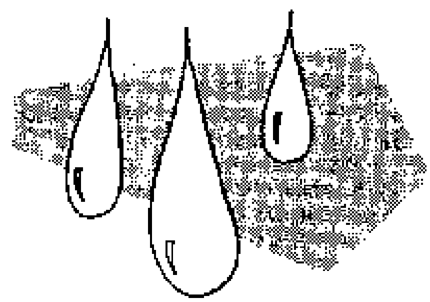
You'll find details on the wall systems in the construction detail section of this manual.

Vapor Barriers

Before continuing, a discussion of vapor barriers and subtrade scheduling is needed.

Vapor barriers must be installed on the warm side of all single-stud walls and on the back of a double-wall's interior wall. As long as the barrier is no deeper than one-third of the R-value into the wall, you'll have no problems. This is why they can be installed on the double-wall's back side, out of harm's way.

What you must constantly remember is that the barrier must be continuous and have maximum integrity. This means it should run from the footings, completely around the structure, wherever vapor



passage or air infiltration could create problems. This means wrapping floor headers, framed basement walls, exterior walls, and ceilings.

There are three essentials for good vapor barrier installations: solid backing, continuous sealant at barrier joints, and rigid covering materials.

Solid backing and rigid covering are essential to protect the barrier and allow its fastening. The continuous sealant should be a durable product that won't harden and break away. Researchers in Saskatchewan, Canada, recommend acoustical sealant as a moderately priced, durable product that works well in this application; 3-M #396 "Superbond Film Tape" or equivalent (available from most suppliers) can also be used to seal vapor barrier seams.

To install the vapor barrier, staple it to plates and studs; place a continuous bead of sealant along joint lines and in line with solid backing; overlap the barrier's second sheet and cover the barrier with rigid material.

While maintaining good integrity around partitions is difficult, we recommend framing all exterior walls; installing the roofing and ceiling framing system, placing all batt insulation in the walls, all outlet boxes and envelope-penetrating components (vents, plumbing stacks, etc.), and all wall board on the walls, and then framing partition walls.

However, keep in mind that this process requires coordination with subtrades. The results are desirable and the effort worthwhile. Wall board installation costs should be reduced, while electrical wiring costs may be slightly increased.

When installing windows, insure vapor barrier continuity and seal against the elements. Staple the barrier to the window jamb before installation and place a caulk bead around the trim to bed the window against the sheathing. Finally, caulk to seal the siding-to-window trim joint. This triple seal is highly effective in sealing envelope openings.

Use high-quality caulking with long range durability and paintability. It's a small investment that will minimize call backs for paint cracking, peeling, or separating.

Exercise great care when installing a vapor barrier. There is a series of details on barrier installation in our construction details section. Please refer to those details prior to any construction, in order to understand how the procedure works.

Foundations

A structure's three types of earth connection are slab-on-grade, foundation with wall space, and full basement. Local climate is the primary determinant of insulation levels and installation methods.

In most cases, installing extruded polystyrene on the foundation's exterior surface is the best treatment. Its primary difficulty is the transition to the framed structure above. It's not easy, although flashings, coatings, treated plywood, asbestos board, or vinyl siding can be used.

None of these techniques and materials are ideal, so your choice will be dictated by aesthetics and costs.

You can insulate basement interiors by building interior framing. This technique is more costly and requires care in insulating at the floor joist level to minimize heat bridging and condensation on the rim joist.

Insulate floors above nonheated or vented crawl spaces to at least R-19. Insulation under slab-on-grade or concrete basement floors must be analyzed for climate. Always install vapor barriers under concrete floors to isolate the structure from the surrounding earth and its moisture.

Ventilation and Moisture Control

An energy-efficient structure's third critical element is an air-to-air heat exchanger. It has two functions: to reduce interior humidity levels (energy-efficient buildings don't need humidifiers) and reduce indoor air pollutants (radon, formaldehyde, smoke, and cooking odors).

In the past, we've depended on air infiltration to control both humidity and indoor pollutants. As was evident in our earlier discussion on heat loss, uncontrolled infiltration rapidly becomes the major heat loss component. Thus, we need the benefits of infiltration without the penalties.

The heat exchanger allows home ventilation in a controlled, efficient manner.

A rate of one-fourth to one-half air changes per hour is usually sufficient to control humidity. However, there may be an occasional need for a higher rate to control odors or smoking concentrations. A two-speed fan, with both a 100 and 200 CFM setting, can provide both types of ventilation in a typical residence. For normal use, the lower setting will allow resolution of moisture problems.

An exchanger moves moist, stale air across thin sheets of material, which transfer the heat to incoming cold, fresh outside air. The normal efficiency is 60 to 70 percent.

Exchangers must have a defrosting cycle to prevent icing up. As the warm moist house air is exhausted, it cools. Condensation forms, and if outdoor temperatures are low enough, icing occurs.

Separate the inlet and outlet vents, putting the outlet higher to prevent pollutants from returning to the home. If the vents must be at the same level, separate them by at least five feet.

Exchangers now on the market cost between $800 and $1500. Their cost effectiveness will depend on local utility rates as well as initial costs. In some situations it may be most cost effective to control moisture and air-borne pollutants by simply introducing fresh air directly into the living space by opening windows if initial costs are too high or utility costs are relatively low. While at first glance this idea may seem to defeat the object of superinsulation, injecting a specified volume of air into a house at a specific point is much more efficient than leaking it in at miscellaneous points throughout the home in unknown quantities.

Finally, remember that not all heat exchangers are designed for use in northern climates. Installing exchangers designed for wall or window mounting will present special weatherization problems.

We've provided a list of air-to-air heat exchanger suppliers in our resource list. We suggest you obtain information on all the units, as costs and performances do vary.

HEATING SYSTEMS, APPLIANCES AND DEVICES

A house needs to be viewed as a total system made up of a number of interacting subsystems like space heating, hot water, lighting, and appliances.

If you want to reduce home energy, you must be aware of the structure's subsystem interaction - reducing one subsystem's energy use may increase another's. Depending on the energy type and cost per unit, the result may not be a cost savings.

For example, it's frequently recommended you insulate hot water pipes, water heaters, and furnace ducts or pipes. But, if these systems are carefully insulated and located in a cold climate full basement, they'll lose less heat to the basement space, perhaps causing the basement temperature to drop to the point water pipes might freeze. To prevent this, the furnace would probably be used to supply heat to the basement. If so, what's gained by insulating? The heat from ducts, pipes, and water heater was traded for heat from the furnace.

Insulate heat ducts and pipes located in unheated (i.e., exposed to outside temperatures) crawl spaces or attics because the heat they lose is lost to the total house system. Any heat saved is saved for the entire system.

Preheat tanks that allow a gradual warming of supply water before it reaches the tank have been recommended. Located in a basement, water can be heated by the room air, which in a cold climate is supplied by the furnace or other basement systems.

In a warm climate (if the water's cold), a preheat tank is a good idea.

Another coming energy-saving recommendation is turning off lights, using smaller-sized light bulbs and so on. When considering the home as a system in the winter, lighting will provide heat to the internal space which then doesn't have to be supplied by the furnace. (Reducing the lighting may increase the demand on the furnace.) However, for the air conditioning season, lighting increases internal home heat, increasing the demands made on the air conditioner and in this case, increasing the total home energy use.

Because there's so much variation in housing and personal habits, it's difficult to give short simple statement recommendations. Each home and its occupants need to be considered as a total system, and changes to reduce home energy use must be considered as interactions among home subsystems.

Appliances

Selected appliance cost will reflect home size. Appliances with all the deluxe features won't be any more suitable for a modest home than bottom-of-the-line stripped models will be for a large expensive home.

Energy guide labels are attached to refrigerators, freezers, dishwashers, clothes washers, water heaters, furnaces and room air conditioners manufactured after May 1980.

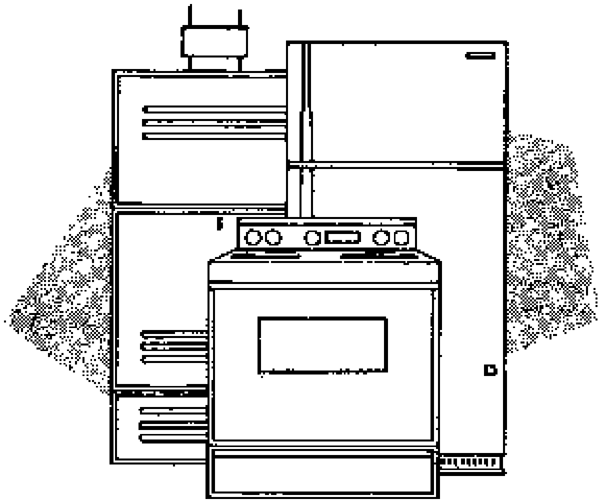
Ranges and clothes dryers don't have labels because there's very little energy use difference between comparable models.

Once you've decided what type, features, and capacity applicance is desired, use the energy guide labels to select the most efficient model on the market.

Caution: Federal law requires builders to leave energy labels on appliances.

Heating Systems

Choosing an energy-efficient residence's heating system can be difficult since few systems are



designed to efficiently provide the small amount of heat needed by most superinsulated structures. Central heating systems are rarely designed to provide less than 50,000 BTUs per hour and efficiency suffers when the systems are grossly oversized.

A separate furnace room is recommended with a combustion furnace. By isolating the combustion device, pollutant control is assured and combustion fresh air can be provided without creating a greater heating load. The furnace should have electronic ignition, a positive flue damper and an outside combustion air duct.

A new market item is the condensing, or pulse combustion, design in gas furnaces. These furnaces are 95 percent efficient. The exhaust gases are between 100 and 200 degrees Fahrenheit allowing the use of a 1.5-inch diameter PVC plastic pipe which can be vented through the wall.

Lennox and Hydrotherm are the only manufacturers presently using the pulse combustion principle. Several gas companies are making condensing furnaces with induced draft blowers. The combustion air supply and flue gas discharge piping is also small diameter plastic pipe. Combustion efficiencies for these units can be over 90 percent.

Wood or coal stoves should be small. Combustion air must be provided and downdraft protection is essential. In a well-sealed structure, air will be drawn in through any opening if a pressure differential occurs. If flue gases are drawn down the stack and out of the stove, it can prove quite dangerous.

Electric baseboard and radiant heating systems have been popular in highly insulated structures because they're easily sized to match the load. Because no flue stack or chimney is needed, envelope penetrations are minimized.

Refrigerators

The temperature difference between a kitchen and the refrigerator's interior is the major factor in determining refrigerator energy use. Therefore, the major requirement is locating the appliance in a cool place in the kitchen, away from such heat sources as the range, heat vents, radiators, and sunshine.

Frost-free or automatic defrost refrigerators are often recommended.

Manual defrost refrigerators are inefficient if the frost is more than ¼ inch thick. Unfortunately, they're frequently kept undefrosted, and some families would find them too small.

In a cycle, or partially automatic defrost model, only the freezer needs defrosting. These appliances are usually cheaper than automatic defrosters, and their freezers will keep ice cream firm. (Ice cream stored in autodefrost refrigerators is often soft.)

Ranges

Studies generally reveal many of the range's extra features are unused, with the self-cleaning oven the sole exception. In 1980, 40 percent of the electric ranges sold had self-cleaning ovens. Except for the very modest homes, look for a range with this feature and a minimum of others.

Energy used by the self-cleaning feature costs about 25 cents per operation. Because of their extra insulation, the self-cleaners use less energy for normal baking.

Ranges lack the energy label because there's very little difference in model efficiency. However, user habits can make a 50 percent difference in the amount of energy used to prepare the same meal.

Microwave Ovens

Although many people believe microwave ovens save energy, studies indicate this isn't always true. A general guide is that a microwave will use more energy if it's used in place of a range's surface unit. However, it will generally use less energy than a conventional oven. Buy a microwave for convenience, not to save energy.

To remove hot food safely from a microwave, the oven's shelf should be at least six inches below its shortest user's shoulder height.

Range Hoods

Because of the superinsulated home's tighter construction, it's important to remove food preparation odors from the house with a range hood.

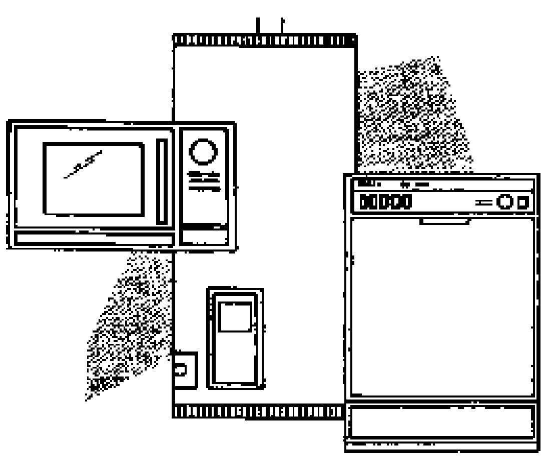
To remove grease and some food odors, use a ductless range hood. The air-to-air exchanger can be installed to supply ventilation air to the kitchen area.

Dishwashers

In 1967, 18 percent of America's homes contained dishwashers. By 1979, the figure had risen to 43 percent.

If possible, include a built-in dishwasher. (Portable models are less convenient since the sink can't be used while the appliance is in operation.)

The amount of water needed to hand- or machine-wash dishes depends on a person's washing habits. Some hand washers use much more water than an automatic dishwasher while other use less.



Air Conditioners

While highly energy-efficient air conditioners cost less to operate, they're also more expensive to buy. And, because of the short cooling season in North Dakota, life cycle costing is important for this appliance.

Lighting

Avoid recessed light fixtures on ceilings below insulated attic spaces; they generally can't be covered with insulation. Also avoid using ceiling-mounted fixtures as they cause problems with ceiling-vapor barriers and create infiltration routes.

Use fluorescent lamps whenever possible. They give more light for the electricity they use.

One major objection to fluorescent lighting is its effect on color. Now, however, fluorescent bulbs come in a variety of colors, and deluxe warm white flatters skin tones. Another objection is the light fixture, which some homeowners consider ugly. More attractive models are starting to come on the market so look and ask for them.

Water Heaters

Some people estimate water heating uses about 12.5 percent of North Dakota's home energy. As less total energy is needed for space heating, this percentage will rise.

Some ways the builder can reduce hot water energy use include buying an efficient water heater and locating it to minimize pipe runs and clustering plumbing.

Some people recommend water heaters to be set at 120 degrees Fahrenheit to save energy. However, if there's a dishwasher in the house, its water needs to be set at 140 degrees to clean and sanitize the dishes. This is especially true when low phosphate dishwashing detergents are used. (Almost all dishwashing detergents sold in the eastern half of North Dakota and all of Minnesota are low phosphate.) Some newer model dishwashers have an internal water heater that raises water temperature 10 to 15 degrees.

In some households, lowering the water heater setting to 120 degrees means running out of hot water more often. Less cold water is mixed with hot water and a larger hot water volume is used. (The total volume of water used doesn't change.)

Windows

Windows provide light, ventilation, and visual connection with the outdoors. Unfortunately, they also create large winter heating and summer cooling loads for the amount of area they occupy in the building envelope. Each square foot of double-glass costs as much to heat in a year as 20 square feet of an R-40 wall.

Windows can create large infiltration heat losses if they don't have an excellent sealing system when closed. Casement, awning, and hopper windows tend to be more airtight than double-hung or sliding windows. Investing in high quality is a high priority since performance improvements are difficult once windows have been installed.

Conduction heat loss during the heating season remains a major problem. Easily installed, automatic, inexpensive and visually pleasing ways of insulating windows remain the ultimate solution. Unfortunately, available systems for insulating windows don't meet these specifications. Builders should familiarize themselves with available products and choose one or two they like for an optional package.

Currently, most consumers will be able to afford window night insulation only if they can build and install it themselves. Consult the books listed under window treatments in the bibliography for available systems and some of their problems.

Take care when designing an energy-efficient structure's window placement. Two considerations to keep in mind are:

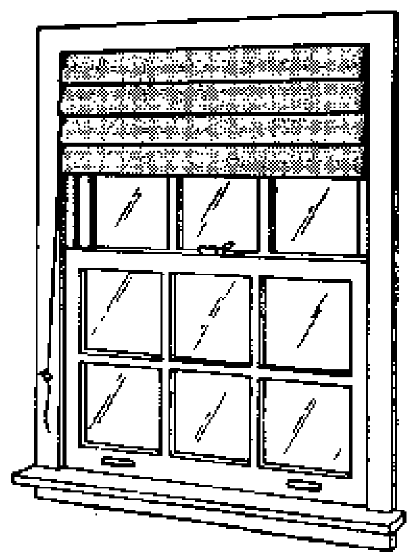
1. Because windows are such energy losers, the majority should face south so solar energy can be used to offset the losses.
2. Because summer solar gain can quickly overheat an unshaded superinsulated structure, restrict windows on the east and west walls and provide a means of shading south-facing windows.

University of Saskatchewan researchers have three rules of thumb that can help you size solar windows and keep them under control. (Remember, oversizing the solar window system can mean creating a solar oven.)

Rule 1: In superinsulated wood frame construction with gypsum wallboard, limit south-facing windows to 6 percent of the floor area. This will prevent overheating in spring and fall. If larger areas of glass are used, provide for extra mass or good ventilation. (Concrete basements insulated on the outside provide a large mass for heat storage and will tolerate greater window area.)

Rule 2: If more than 6 percent south-facing windows are provided, include extra mass. A rough rule of five square feet of 4-inch thick masonry per square feet of glass in excess of 6 percent should help dampen the temperature fluctuations.

Rule 3: Provide an overhang to allow full sun into the window from November 21 until February 1. Provide for circulation of heated air to non-solar spaces for even heat distribution. A small duct and fan will do. And, in structures of more than one story, concentrate windows in lower stories. For example, a 70 percent bottom story and a 30 percent top story blend will help cut upper story heat stratification in a two-story structure.



Cooling

While cooling loads aren't large anywhere in North Dakota, maintaining comfort levels is necessary.

Preventing Heat Gain

A structure built for winter efficiency is already designed to prevent many overheating problems. The key to stopping overheating is excluding sunlight. Awnings, shutters, trellises, vegetation and bamboo or lath screens all function as excellent protection from excess sunlight. Minimizing east and west windows also greatly reduces potential overheating problems.

Prevention strategies usually cost less than other techniques.

Construction Economics and Marketing

Building an energy-efficient home is good common sense. And, most of today's buying public is aware of the economic advantages of owning such a structure. However, to effectively market energy conservation, you'll need to be able to demonstrate its economics on paper.

Buyer concerns will be about benefits outweighing costs and how soon the additional investment pays for itself. A standard approach to answering these concerns has been the simple payback analysis. For example, a $500 investment in triple-glazed windows will, if it saves $100 per year, pay for itself in five years.

However, the simple payback analysis has several drawbacks. First, cash flows beyond the payback year are neglected. Second, payback discriminates against long-lived projects, and, third, it ignores inflation, interest rates, and the time value of money.

But, if simple payback analysis contains these disadvantages, what can you, as the builder, use to show your buyers the economic advantages of energy-efficient construction?

The best way to determine the long term benefits to your buyers is called life cycle costing; a simple way of charting the cash flows of costs and savings over a given number of years. However, while life cycle is a simple method, it can also prove difficult and time consuming. A number of factors, such as mortgage interest, inflation rates and long term energy prices must be estimated. They then must be combined with projected costs and savings to estimate cash flows over a given time.

If you have access to a good computer program on life cycle costing, the process can be quick. But, even with this help, you'll still have to interpret the results for your prospective clients. If you don't have a computer, you'll have to manually calculate.

If it's starting to look like everything is getting a bit complicated, you're probably asking yourself what method you can use to demonstrate superinsulation's economic benefits.

Mike Scott, at the Mid-American Solar Energy Complex (MASEC), developed a good technique amounting to a simplified life cycle cost analysis tracing "cash-out-of-pocket" energy costs. It's quick to compute and very understandable to buyers.

The first step is calculating the heat loads for the major components of the proposed structure. You can then compare these loads graphically to those of homes built according to conventional standards. You might also try putting some utility costs on the graphs to demonstrate the financial implications of tight construction.

Specifications for the homes in Figure 3 are given in Table 2. Additional construction costs for the tighter house appear in Table 3. (Remember, these additional construction costs are estimates made on 1985 as examples for this manual. Your costs may be higher or lower.)

The procedure for simplified life cycle costing is given in Table 4. You'll need to calculate:

1. The additional investment in conservation for the structure you propose building.
2. The additional annual mortgage payment resulting from this added investment.
   (To derive this figure, multiply the additional investment in conservation (from Table 3) times the appropriate Capital Recovery Factor from Table 5.)
   Example: The Capital Recovery Factor for 14 percent interest over 30 years is .1428. If the additional investment was $3,659, then the annual increase in mortgage cost would be $523. ($3,659 × .1428 = $523 per year.)
3. Calculate the annual utility savings from the procedures outlined on pages 6 through 12. Express these savings as a percentage of what the costs would be for a house built to conventional standards.

Let's interpret the results of the example in Table 4. A conventional house is used as a basis for comparison.

No additional investment in conservation is made in the conventional house so there's no additional mortgage or utility savings. Out-of-pocket energy costs will be $893 per year and total energy costs (at

Figure 3. Major Heat Loads (BTUh/°F)

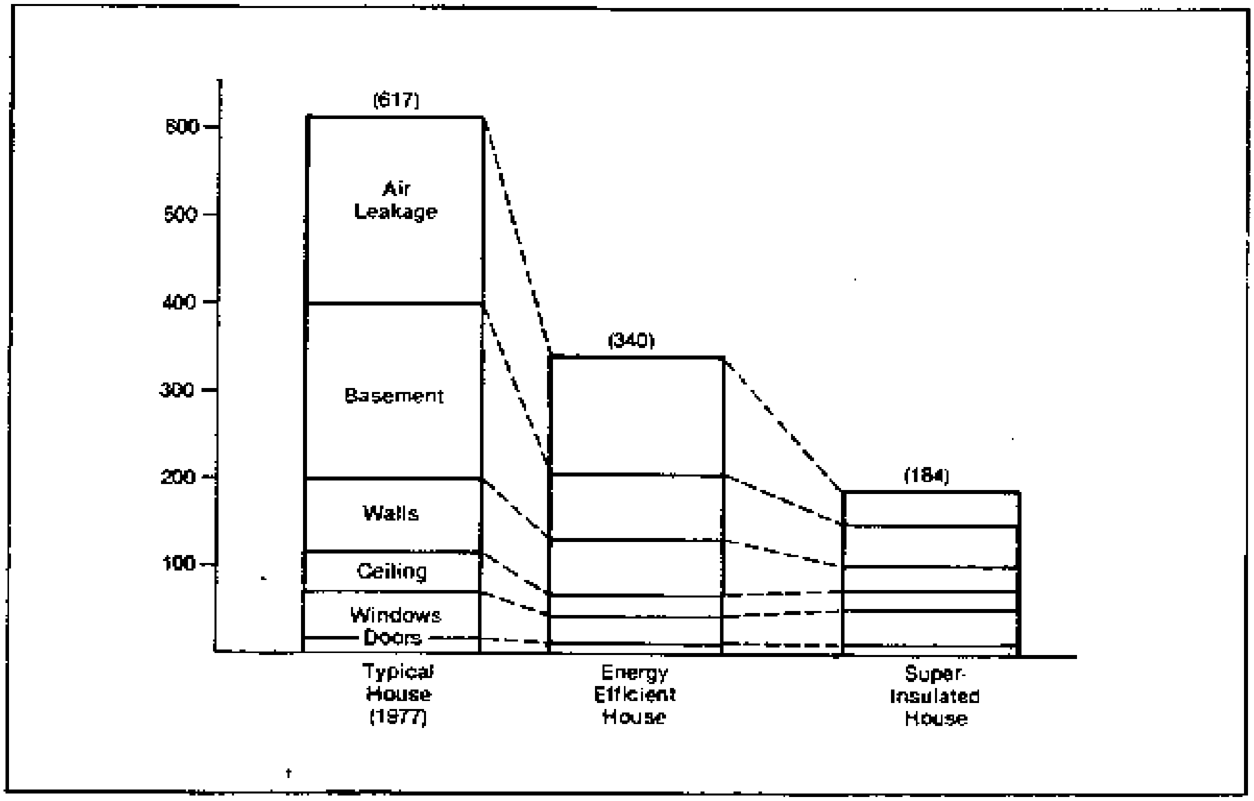


Table 2. House Construction Specifications*

	Typical House-(1977)	Energy-Efficient House	Superinsulated House
Wall R-values	12.5	19	32
Ceiling R-values	25	39	60
Infiltration	.7 ACH	.4 ACH	.1 ACH
Basement Insulation	1" to Footings	1" to Footings 6" on Rim Joist	1" to Footings 3" to Frostline 6" on Rim Joist
Windows	Double Glazed	Triple Glazed	Triple Glazed
Door R-values	3.6 (Wood)	15 (Steel/Foam Core)	15 (Steel/Foam Core)
Heating System Annual Heat Load	20 KW 89.3 MMBTUs	10 KW 53.9 MMBTUs	5 KW 21.4 MMBTUs
Annual Energy Cost	$893 (@$10/MMBTUs)	$539	$214
Annual Energy Savings	$0	$354	$679
Additional Construction Costs	$0	$1,955	$3,658

*24 x 48 House

Table 3. Additional Construction Costs

Building Component	Energy-Efficient House	Superinsulated House
Infiltration	$ 200	$ 200
Basement	50	615
Walls	191	720
Ceiling	194	484
Windows	360	600
Doors	160	240
Heat Exchanger	800	800
Total	$1,955	$3,659

Table 4. Simplified Energy Life-Cycle Cost Comparison

		Typical 1977 House	Energy-Efficient House	Superinsulated House
#1	Additional Energy Conservation Investment	$0	$1,955	$3,659
#2	Additional Annual Mortgage Payment @14%	$0	$279	$523
#3	Annual Utility Cost	$893	$539	$214
#4	Annual Utility Savings	0%	40%	76%

Cumulative Out-of-Pocket Life Cycle Costs (#2 and #3)

Year	Typical 1977 House	Energy-Efficient House	Superinsulated House
1	$ 893	$ 818	$ 737
2	$ 1,786	$ 1,636	$ 1,474
3	$ 2,679	$ 2,454	$ 2,211
4	$ 3,572	$ 3,272	$ 2,948
5	$ 4,465	$ 4,090	$ 3,685
6	$ 5,358	$ 4,908	$ 4,422
7	$ 6,251	$ 5,726	$ 5,159
8	$ 7,144	$ 6,544	$ 5,896
9	$ 8,037	$ 7,362	$ 6,633
10	$ 8,930	$ 8,180	$ 7,370
30	$26,790	$24,540	$22,110

Table 5. Nominal Capital Recovery Factors

Year	.04	.05	.06	.07	.08	.09
	Interest Rate					
1	1.04000	1.05001	1.06001	1.07000	1.08000	1.09001
2	0.53020	0.53781	0.54544	0.55310	0.56077	0.56847
3	0.36035	0.36722	0.37411	0.38106	0.38804	0.39506
4	0.27549	0.28202	0.28860	0.29523	0.30192	0.30867
5	0.22463	0.23098	0.23740	0.24389	0.25046	0.25709
6	0.19076	0.19702	0.20337	0.20980	0.21632	0.22292
7	0.16661	0.17282	0.17914	0.18555	0.19207	0.19869
8	0.14853	0.15472	0.16104	0.16747	0.17402	0.18068
9	0.13449	0.14069	0.14702	0.15349	0.16008	0.16680
10	0.12329	0.12951	0.13587	0.14238	0.14903	0.15582
11	0.11415	0.12039	0.12679	0.13336	0.14008	0.14695
12	0.10655	0.11283	0.11928	0.12590	0.13270	0.13965
13	0.10014	0.10646	0.11296	0.11965	0.12652	0.13357
14	0.09467	0.10103	0.10759	0.11435	0.12130	0.12843
15	0.08994	0.09634	0.10296	0.10980	0.11683	0.12406
16	0.08582	0.09227	0.09895	0.10586	0.11298	0.12030
17	0.08220	0.08870	0.09545	0.10243	0.10963	0.11705
18	0.07899	0.08555	0.09236	0.09941	0.10670	0.11421
19	0.07614	0.08275	0.08962	0.09675	0.10413	0.11173
20	0.07358	0.08024	0.08719	0.09439	0.10185	0.10955
21	0.07128	0.07800	0.08501	0.09229	0.09983	0.10762
22	0.06920	0.07597	0.08305	0.09041	0.09803	0.10591
23	0.06731	0.07414	0.08128	0.08871	0.09642	0.10438
24	0.06559	0.07247	0.07968	0.08719	0.09498	0.10302
25	0.06401	0.07095	0.07823	0.08581	0.09368	0.10181
26	0.06257	0.06956	0.07690	0.08456	0.09251	0.10072
27	0.06124	0.06829	0.07570	0.08343	0.09145	0.09974
28	0.06001	0.06712	0.07459	0.08239	0.09049	0.09885
29	0.05888	0.06605	0.07358	0.08145	0.08962	0.09806
30	0.05783	0.06505	0.07265	0.08059	0.08883	0.09734

Year	.10	.11	.12	.13	.14	.15
1	1.10000	1.11000	1.12000	1.13001	1.14000	1.15000
2	0.57619	0.58394	0.59170	0.59949	0.60729	0.61512
3	0.40212	0.40922	0.41635	0.42353	0.43073	0.43798
4	0.31547	0.32233	0.32924	0.33620	0.34321	0.35027
5	0.26380	0.27057	0.27741	0.28432	0.29128	0.29832
6	0.22961	0.23638	0.24323	0.25015	0.25716	0.26424
7	0.20541	0.21222	0.21912	0.22611	0.23319	0.24036
8	0.18745	0.19432	0.20130	0.20839	0.21557	0.22285
9	0.17364	0.18060	0.18768	0.19487	0.20217	0.20957
10	0.16275	0.16980	0.17698	0.18429	0.19171	0.19925
11	0.15396	0.16112	0.16842	0.17584	0.18339	0.19107
12	0.14676	0.15403	0.16144	0.16899	0.17667	0.18448
13	0.14078	0.14812	0.15568	0.16335	0.17116	0.17911
14	0.13575	0.14323	0.15087	0.15867	0.16661	0.17469
15	0.13147	0.13907	0.14682	0.15474	0.16281	0.17102
16	0.12782	0.13552	0.14339	0.15143	0.15962	0.16795
17	0.12466	0.13247	0.14046	0.14861	0.15692	0.16537
18	0.12193	0.12984	0.13794	0.14620	0.15462	0.16319
19	0.11955	0.12756	0.13576	0.14413	0.15266	0.16134
20	0.11746	0.12558	0.13388	0.14235	0.15099	0.15976
21	0.11562	0.12384	0.13224	0.14081	0.14955	0.15842
22	0.11401	0.12231	0.13081	0.13948	0.14830	0.15727
23	0.11257	0.12097	0.12956	0.13832	0.14723	0.15628
24	0.11130	0.11979	0.12846	0.13731	0.14630	0.15543
25	0.11017	0.11874	0.12750	0.13643	0.14550	0.15470
26	0.10916	0.11781	0.12655	0.13565	0.14480	0.15407
27	0.10826	0.11699	0.12590	0.13498	0.14419	0.15353
28	0.10745	0.11626	0.12524	0.13439	0.14366	0.15306
29	0.10673	0.11561	0.12466	0.13387	0.14320	0.15265
30	0.10608	0.11502	0.12414	0.13341	0.14280	0.15230

constant energy prices) will be $26,790 over a 30-year mortgage.

On the other hand, the energy-efficient home needs an additional conservation investment of $1,955. The annual mortgage is increased $279 per year, but the annual utility cost is reduced to $539 per year (a savings of $354).

Total out-of-pocket energy costs (additional mortgage + utility costs) are $818 per year. This represents a $75 savings the first year the home is owned. Over a 30-year mortgage, this will yield $2,250 in savings at constant fuel prices. Increases in real prices will increase savings further.

Finally, if the superinsulated house requires an extra $3,659 conservation investment, mortgage costs will increase by $523 per year, but utility costs will decrease to $214. Total out-of-pocket energy costs will be $737 per year, a cash savings of $156 per year compared to the conventional home.

Discovering how cost-effective energy conservation is surprises many people. It's up to you to demonstrate its financial benefits to the public. Showing potential buyers they can save money the first year they own the new home you've built can go a long way toward marketing your product.

Retrofitting

Not everyone has the luxury of building a new energy-efficient home. Projections show 70 percent of the buildings we'll be living in by the year 2000 are already here.

It's obvious dealing with existing energy wasters can be a major building concern and will profit those who can do it well. Unfortunately, retrofitting isn't always easy or cheap.

Remember the vapor barrier rules stated earlier:

1. You must install a vapor barrier on the warm (interior) side of insulation.
2. The vapor barrier must be continuous and have integrity (i.e. no holes or gaps).
3. You can place the vapor barrier in the insulation as long as it's no more than one-third of the way in, coming from the warm side.

Retrofitting falls into four main categories: hole plugging, easy-access retrofits, system improvements, and renovation.

Hole Plugging

These are the low-cost, high-payback tasks many of us have done (or can easily do), such as caulking cracks, holes, and gaps, and weatherstripping doors and windows.

Make outside vents airtight when not in use and caulk along the baseboard and around interior windows. The chart on caulking and weatherstripping materials is taken from "The Well Tempered House" and gives good comparisons of the materials.

Easy-Access Retrofits

Installing storm windows and attic insulation, automatic setback thermostats for furnaces, water heater insulation and outlet and switch cover insulators are all popular and useful easy-access retrofits. Their payback is longer so consider them the second level of retrofitting.

Storm Windows and Doors

Storm windows are necessary retrofits on single-glazed structures, and can be economical in many double-glazed situations. Take care to install quality storm windows and ensure a good fit. A 1-inch silicone caulking seam isn't a substitute for a proper fit.

Consider storm doors for all exterior doors, including patio doors.

Attic Insulation

Attic insulation is a common retrofit. Depths beyond 24 inches may not be justified unless they're part of a comprehensive retrofit.

RETROFITTING ANALYSIS SHEET

Category	Condition			
	Not Present	Needs Replacement	Needs Upgrading	Is Adequate
Hole Plugging				
Caulking				
Doors				
Windows				
Exterior Seams				
Interior Seams				
Weatherstripping				
Doors				
Windows				
Dampers				
Furnace Flue				
Fireplace or Stove				
Dryer				
Kitchen & Bathroom vents				
Easy Access				
Storm Windows				
Storm Doors				
Setback Thermostats				
Hot Water				
Furnace				
Attic Insulation				
Attic Vapor Barrier				
Domestic Hot Water				
Showerhead				
Aerators				
Heater Insulation				
Line Insulation				
Basement Insulation				
Floor Insulation				
System Improvements				
Central Heating Systems				
Flue Damper				
Stove				
Refrigerator				
Hot Water Heater				
Window Insulation				
Renovation				
Interior Finish				
Exterior Finish				
Vapor Barriers				
Conservation & Solar Additions				
Greenhouse or Sun room				
Buffer Additions				
Thermosyphoning Air Panels				

Automatic Setback Thermostats

Automatic setback thermostats for furnaces are good retrofits. However, while both take energy conservation out of the conscious-effort stage and into the automatic stage, they may create excessive peak demands if widely used.

Basement Wall and Floor Insulation

Crawl spaces and unheated basements require special attention. Most crawl spaces are provided with ventilators which can be closed during the winter if moisture is not a problem. The crawl space floor should be covered with two layers of 6-mil polyethylene to prevent moisture migration from the ground into the crawl space. If plumbing pipes are located in the crawl space it is necessary to make sure that adding insulation will not cause freezing of the pipes. At least 2 inches of rigid board insulation can be applied to the inside walls of the crawl space and the ventilators closed during the winter. If plumbing is not a problem R-19 fiberglass batts can be placed between the floor joist and held in place by wire supports. The floor of an unheated basement can also be insulated in a similar manner using fiberglass batts if plumbing fixtures and pipes are not a problem.

While basement walls can be insulated on the interior or exterior surfaces, interior insulation will probably be cheaper. Ask for Energy Extension Service Bulletin (EES-31), "Cut Foundation Heat Loss."

A target of R-20 is desirable above grade down to two feet below grade. You can justify R-10 to a four-foot depth. Couple attic insulation with floor or basement insulation in all retrofits.

All weather wood foundations are also being used on home construction. The design criteria for this type of basement wall must be from a reliable approved professional source. This type of foundation can be quickly erected by the framing crew, and when properly finished, provides a basement wall with good insulation quality.

Wall Outlets and Switch Cover Insulation

Infiltration can be a real problem in older homes. However, you can effectively reduce this infiltration by placing insulators and plugs in exterior wall outlets and switch cover.

System Improvements

Upgrade old and poorly maintained energy-consuming systems to more energy-efficient modern ones. Evaluate appliances, water heaters, and furnaces.

If you're retrofitting, think about downsizing the furnace as part of your program. Coupling furnace replacement with insulation improvements offers the homeowners a greater savings than doing each operation separately. Consider replacing appliances or a water heater as part of the project too.

Window Insulation

Insulating windows as part of a retrofitting project should be considered the same way it is for new construction. The economics should be considered on a case-by-case basis, and familiarity with available systems is helpful. Window treatments with an R-4 will reduce window heat loss up to 50 percent as compared to an R-2 window.

Renovation

We've moved steadily from low-cost retrofits to the most costly. Old structure renovation—either interior or exterior finish repair or replacement—offers the opportunity to complete the energy-conserving retrofit.

It's seldom cost-effective to strip off functional exterior or interior finishes simply to conserve energy.

Compared to savings, it's expensive. But, if you need to renovate, energy conservation can be a minor investment. Cavity walls can be stripped, insulated with batts and recovered with a new finish coat.

Gypsum board and insulation can be placed over the interior surface, straps attached to the exterior and insulation added before the new siding is applied.

We must again stress the vapor barrier's importance. When you install new side wall insulation, always provide a continuous vapor barrier on the insulation's warm side.

Base energy projects on the consumer's benefit. As energy prices escalate, costlier retrofits become better buys.

It's obvious an old structure that needs a furnace replaced or interior finish and/or exterior finish replaced is an ideal candidate for a full scale energy conservation retrofit. Other cases will dictate a wide range of possibilities.

Passive solar greenhouses, sun rooms, thermosiphoning air panels and energy-conserving additions such as vestibules or buffer additions can all be good strategies once retrofitting is finished. They're not replacements for conservation retrofitting, but logical next steps.

The Retrofit Worksheet will help you analyze the possibilities for projects of this sort. Access to utility bills will provide you with use data, which will allow you to better evaluate the retrofit payback. "Major Energy Conservation Retrofits - A Planning Guide for Northern Climate" available from the National Center for Appropriate Technology, P.O. Box 3838, Butte, Montana 59702, has a comprehensive discussion of options.

CONSTRUCTION DETAILS

The sources for construction details are:

Fig. 6: Scott Robinson, MASEC, 8140 26th Ave. So., Bloomington, MN 55420.

Fig. 9: "Superinsulation: A Housing Trend for the Eighties," National Center for Appropriate Technology, P.O. Box 3838, Butte, MT 59701 (one copy free).

Figs. 7, 8, 10, 13, 15, 18, 19, 20: "Energy-Efficient Housing – A Prairie Approach," Office of Energy Conservation, Saskatchewan Mineral Resources, 1914 Hamilton St., Regina, Saskatchewan S4P 4V4.

Figure 4. A 3/8" plywood top stiffens and straightens double walls and creates the desired spacing between them.

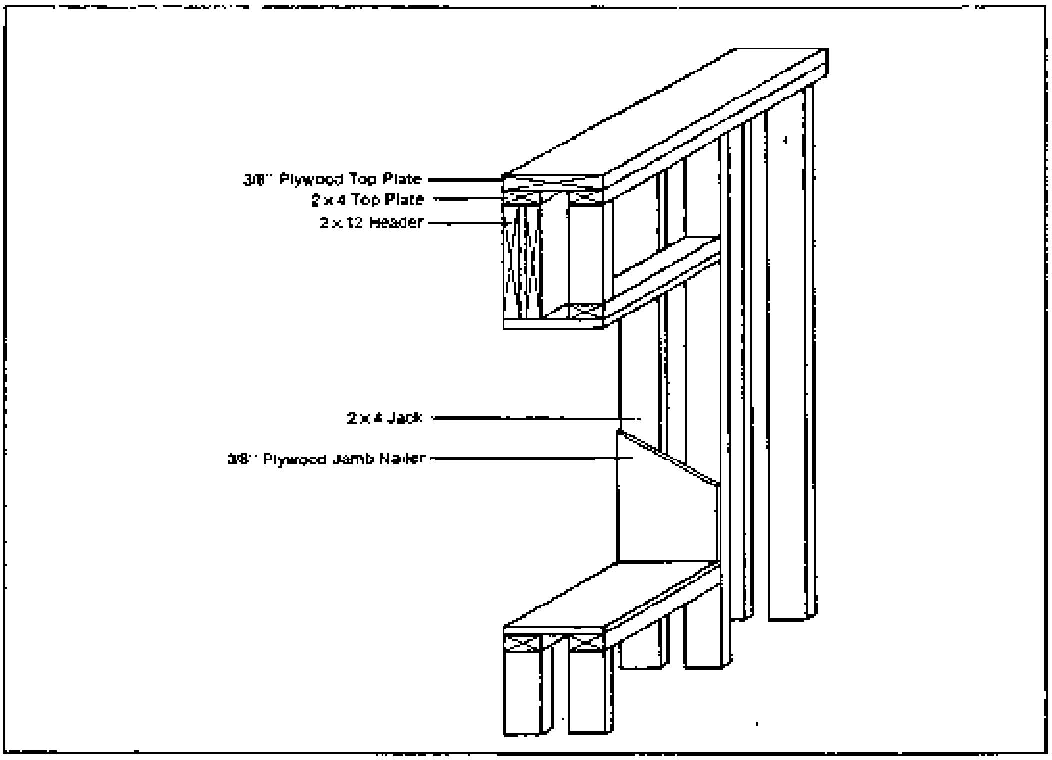
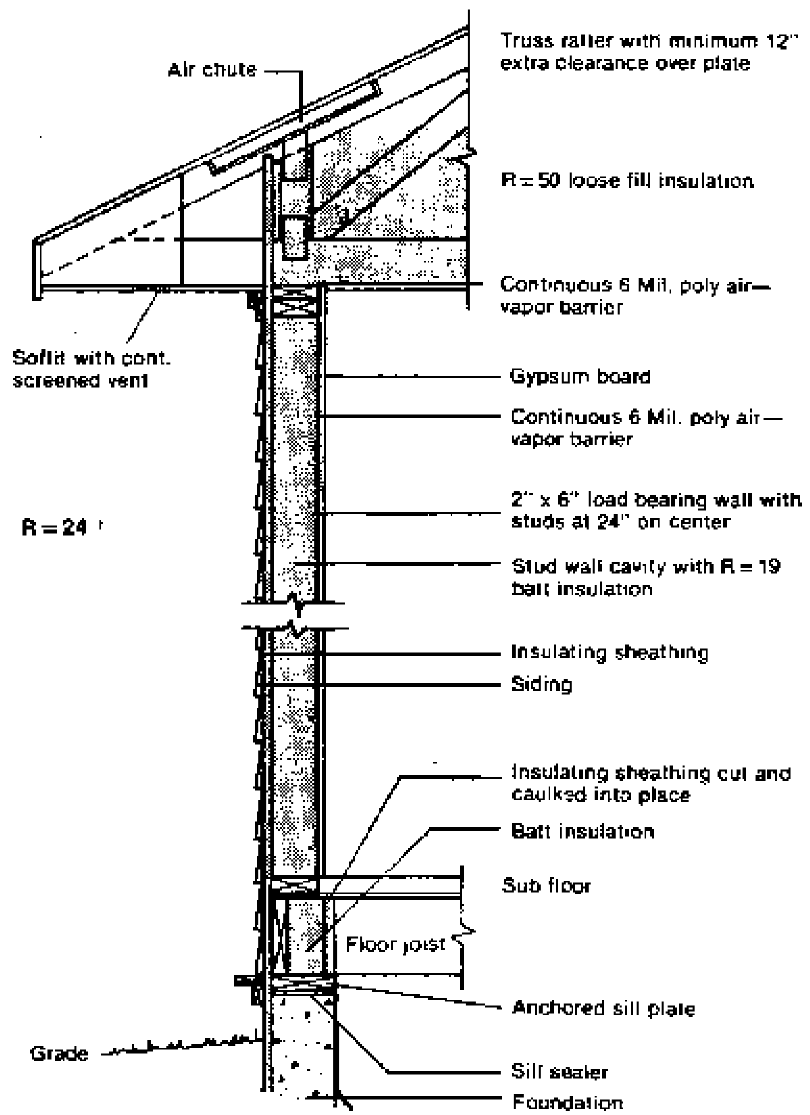


Figure 5. 2" x 6" Single Wall Framing



TYPICAL WALL SECTION

Figure 6. 2 × 8 wall framing.

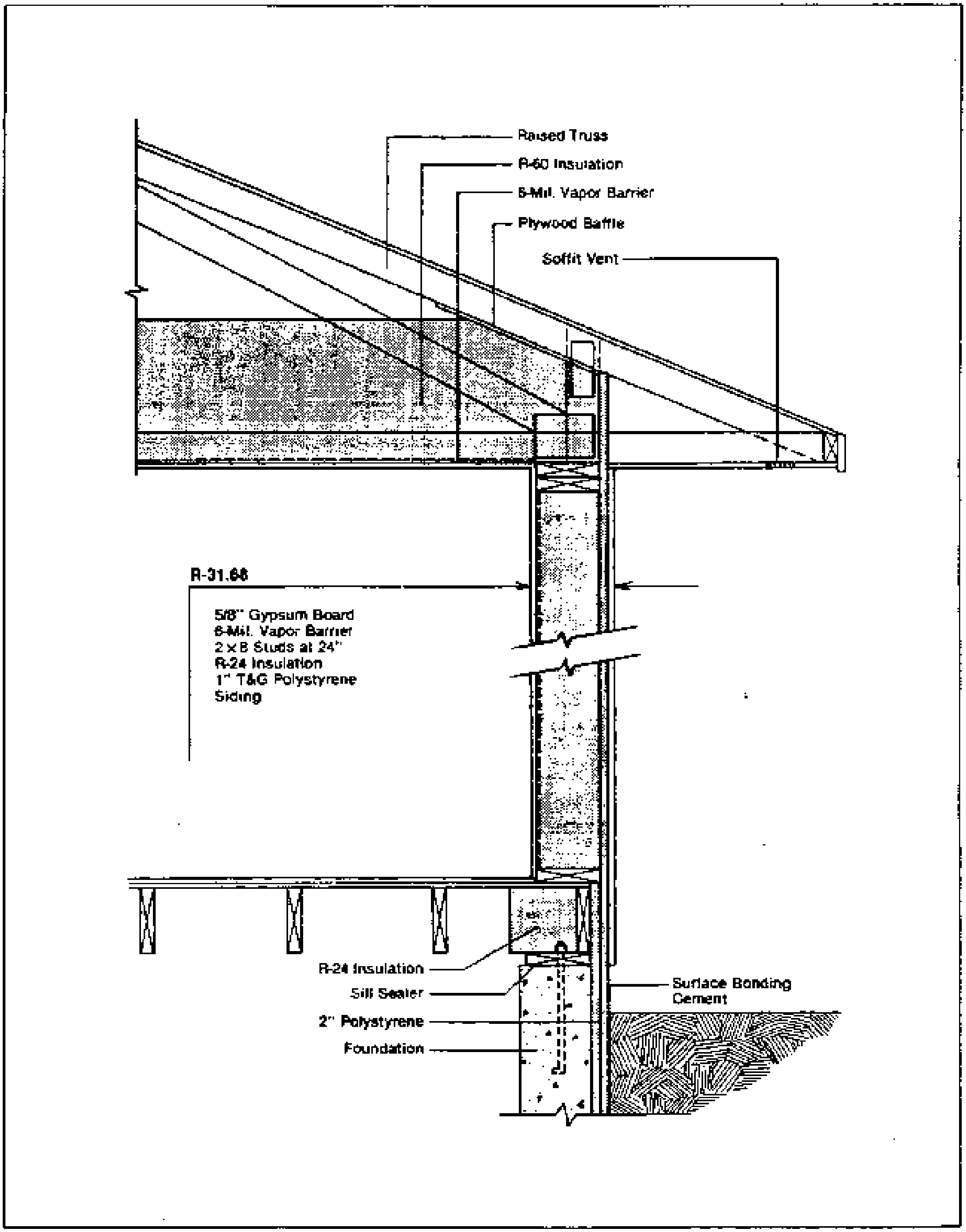


Figure 7. Wall section - vapor barrier detail.

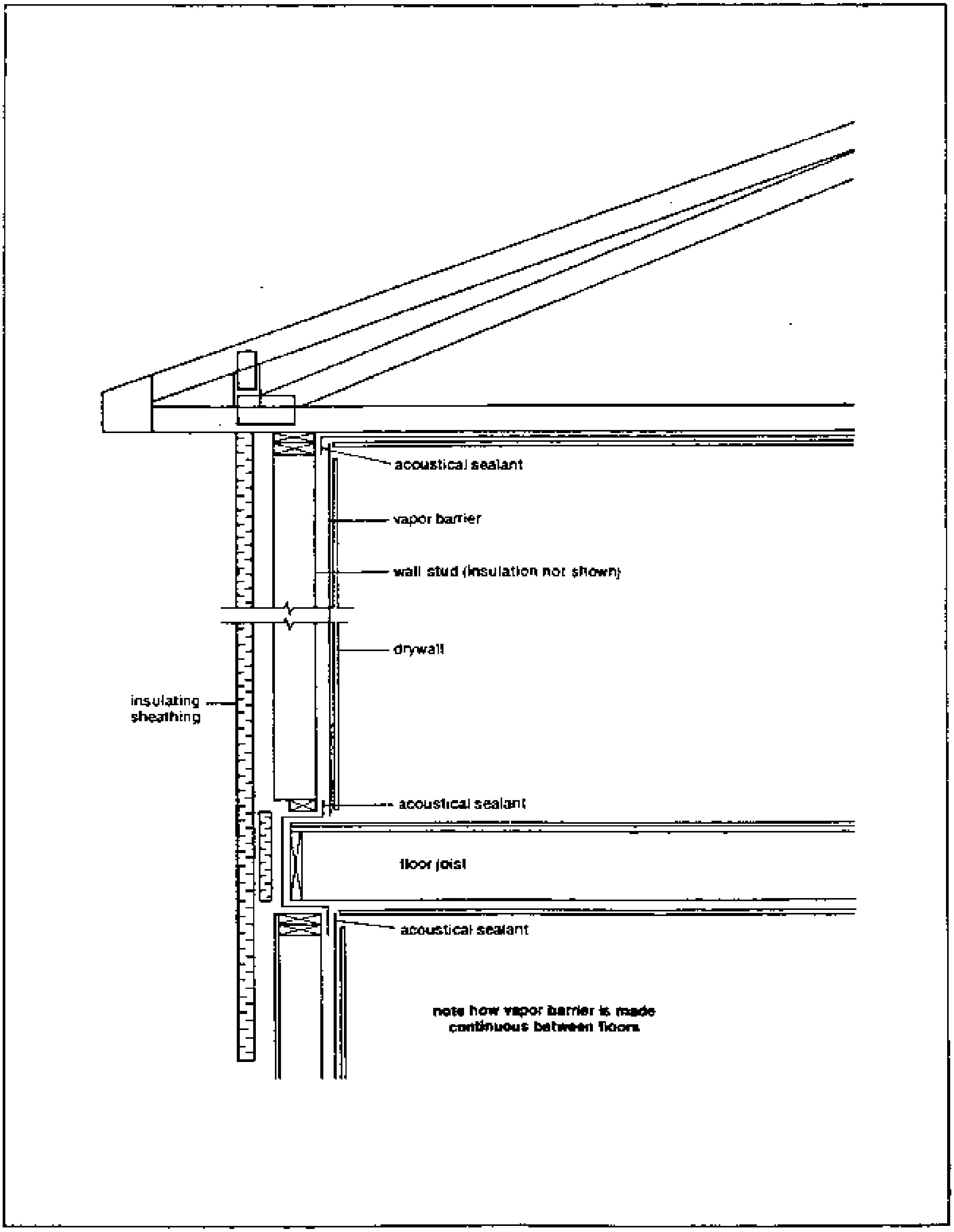


Figure 8. Vapor barrier installation at window.

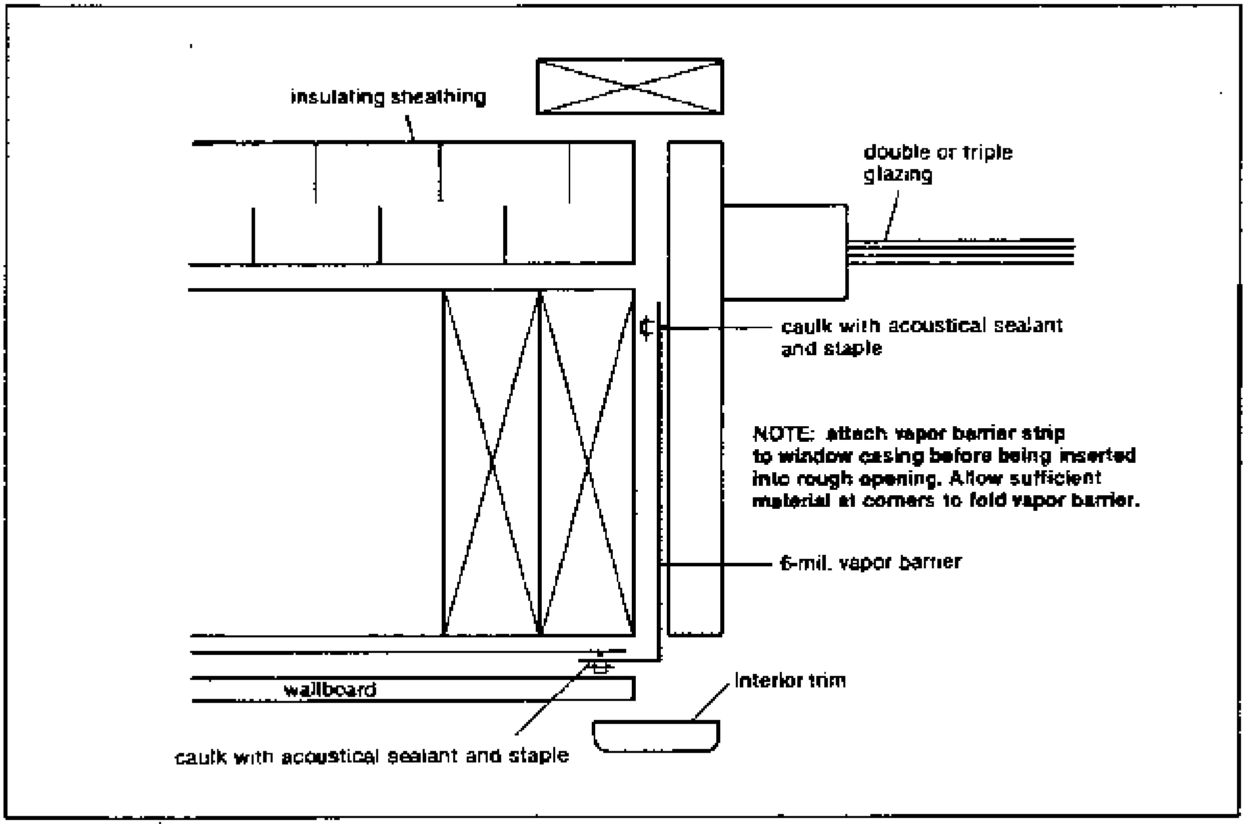


Figure 9. Single-stud wall with exterior insulation system.

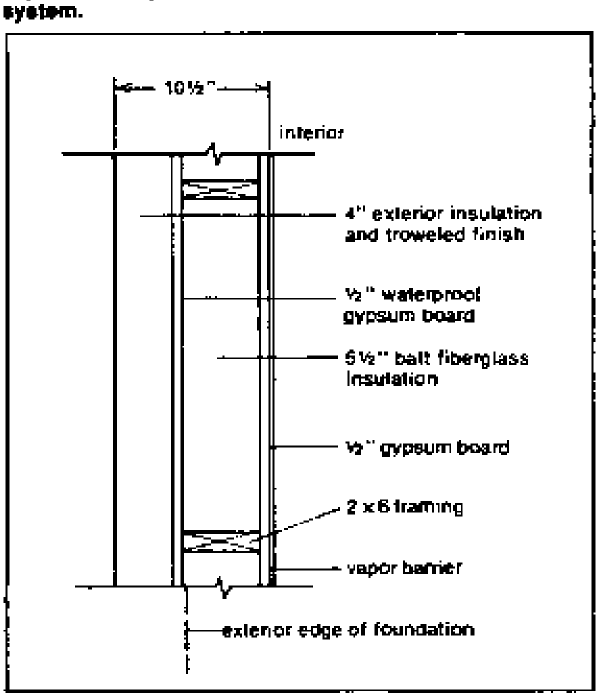


Figure 10. Vapor barrier installation around electrical box.

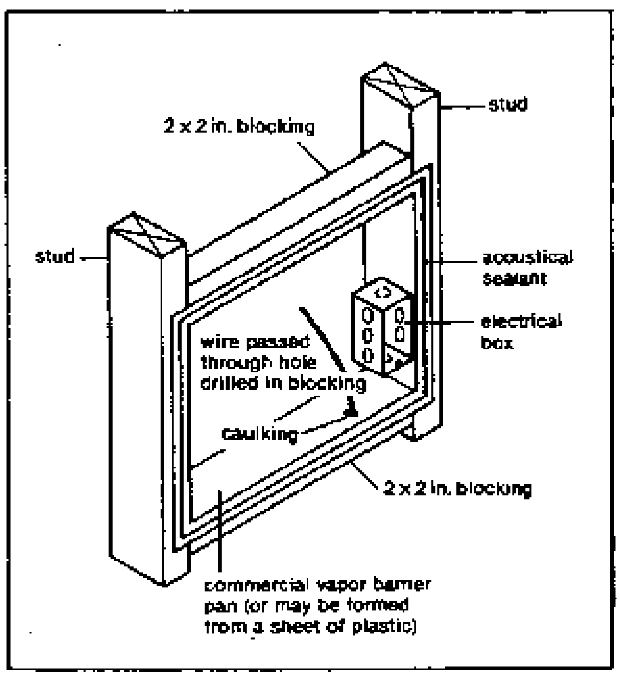
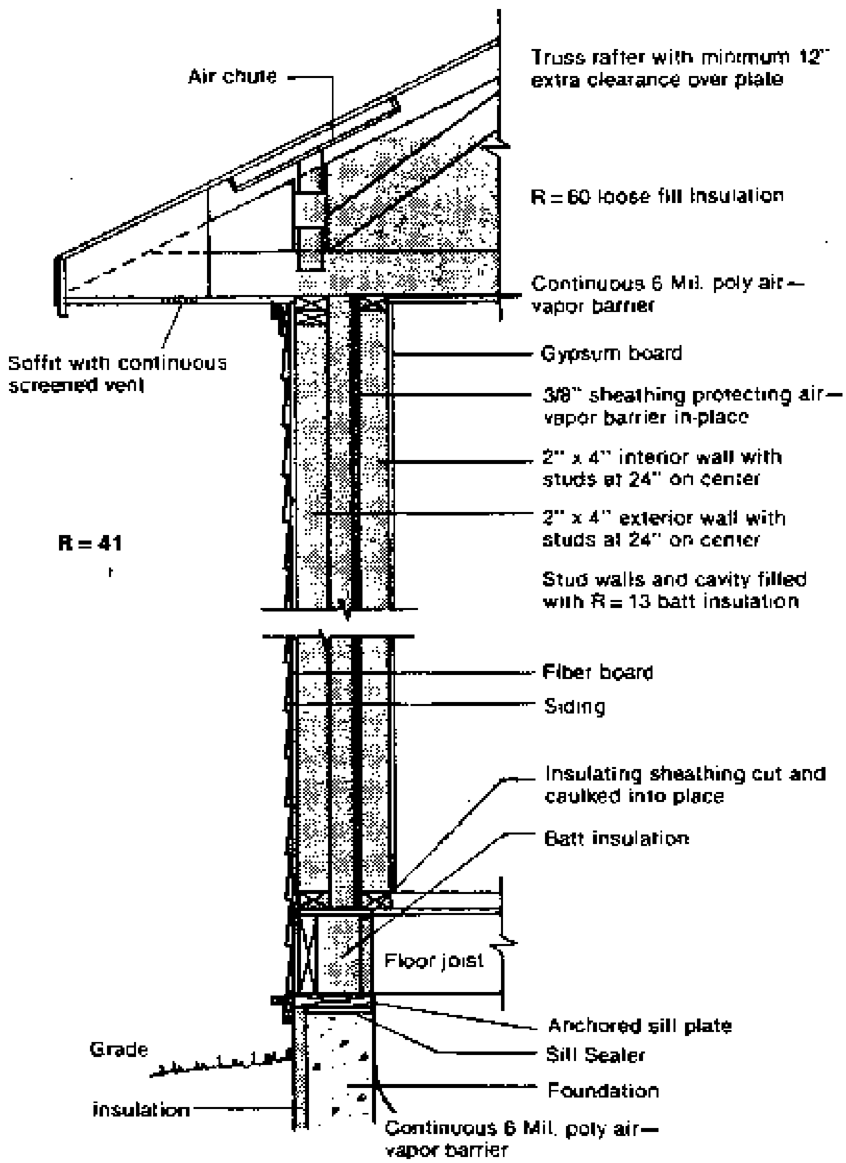
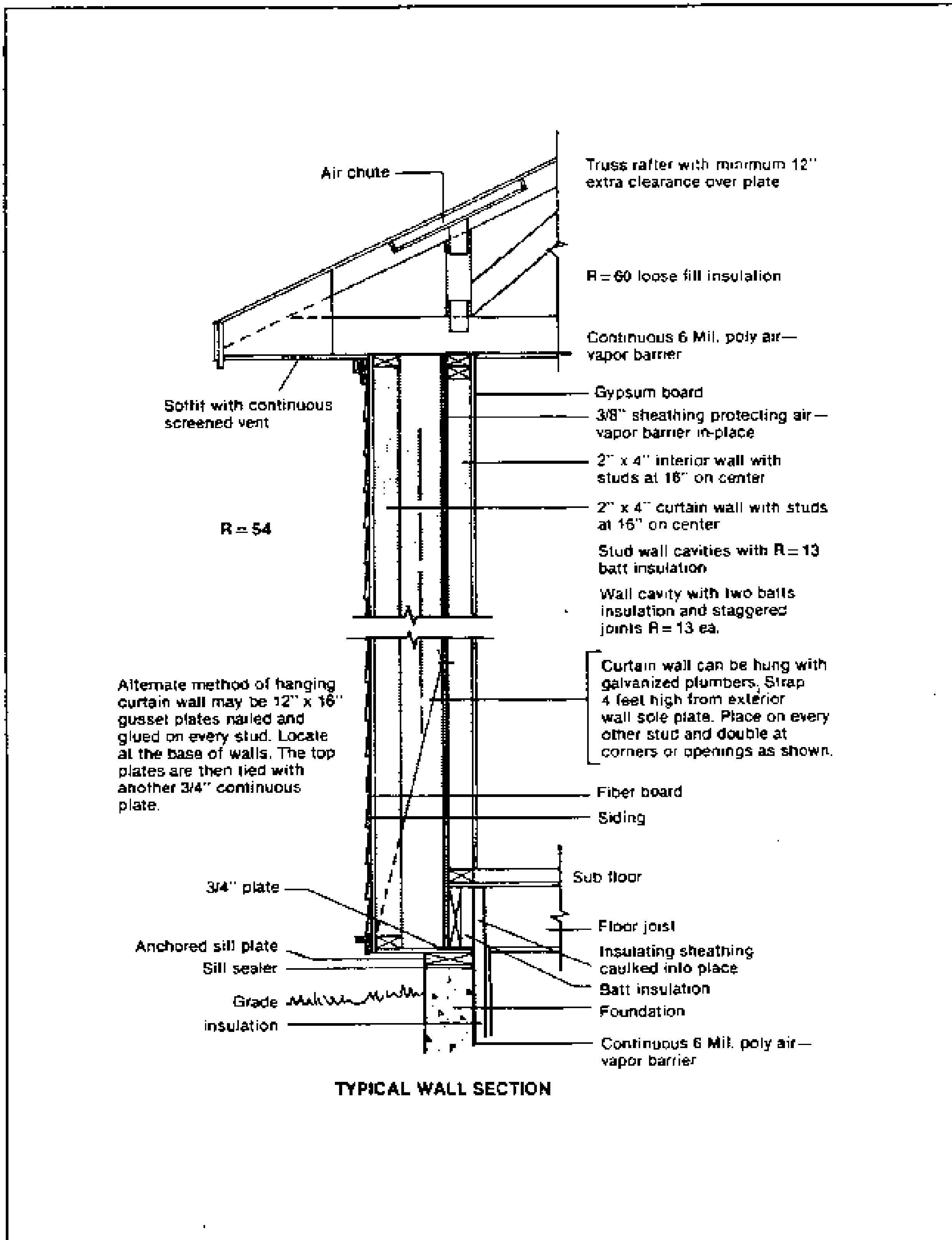


Figure 11. 2" x 4" Double Wall Framing



TYPICAL WALL SECTION

Figure 12. 2" x 4" Curtain Wall Framing



TYPICAL WALL SECTION

Figure 13. Air leakage spots in conventional housing.

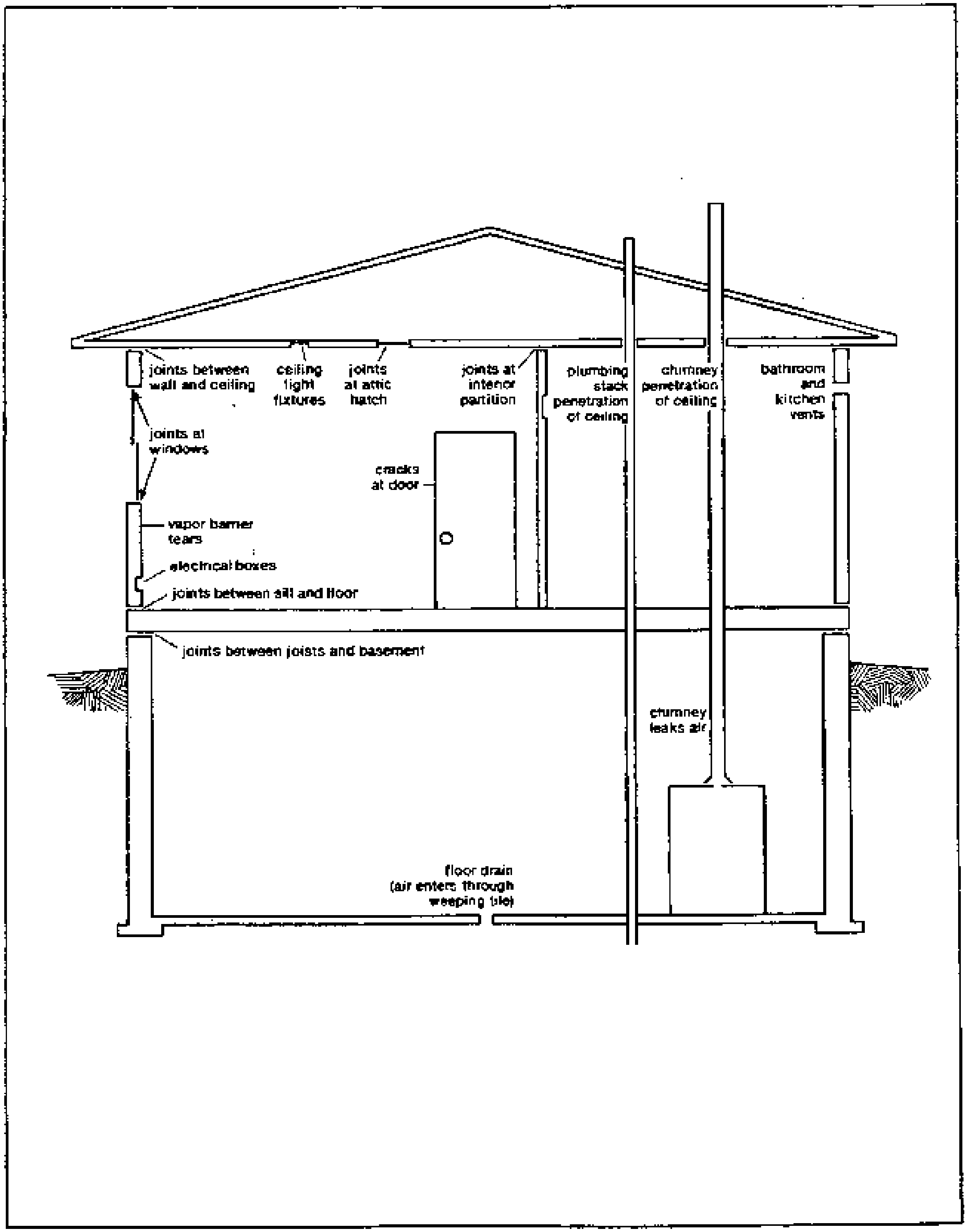


Figure 14. Technique for joining vapor barrier sheets on wall studs. (insulation not shown)

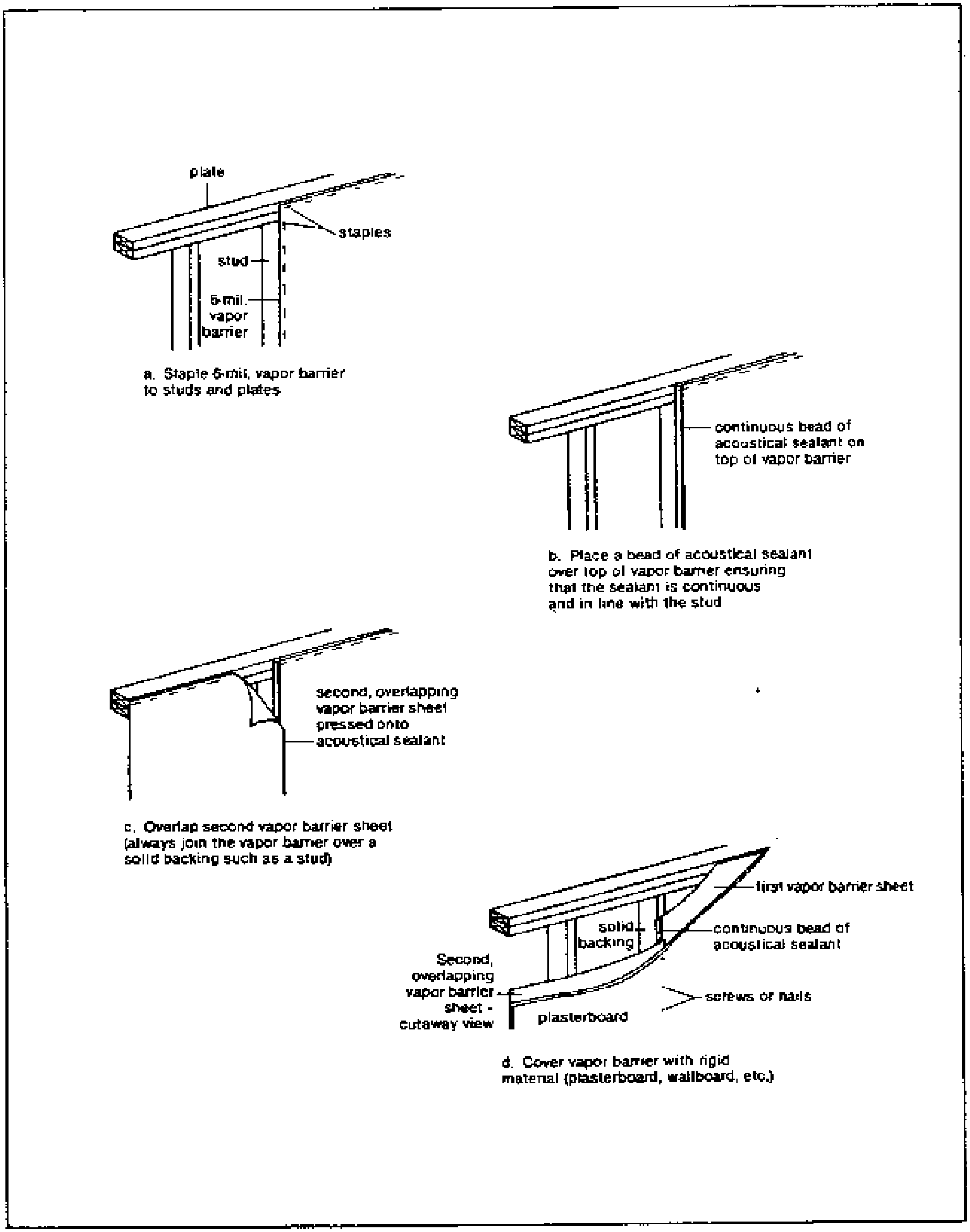


Figure 15. Perferred duct arrangement for exhaust fans.

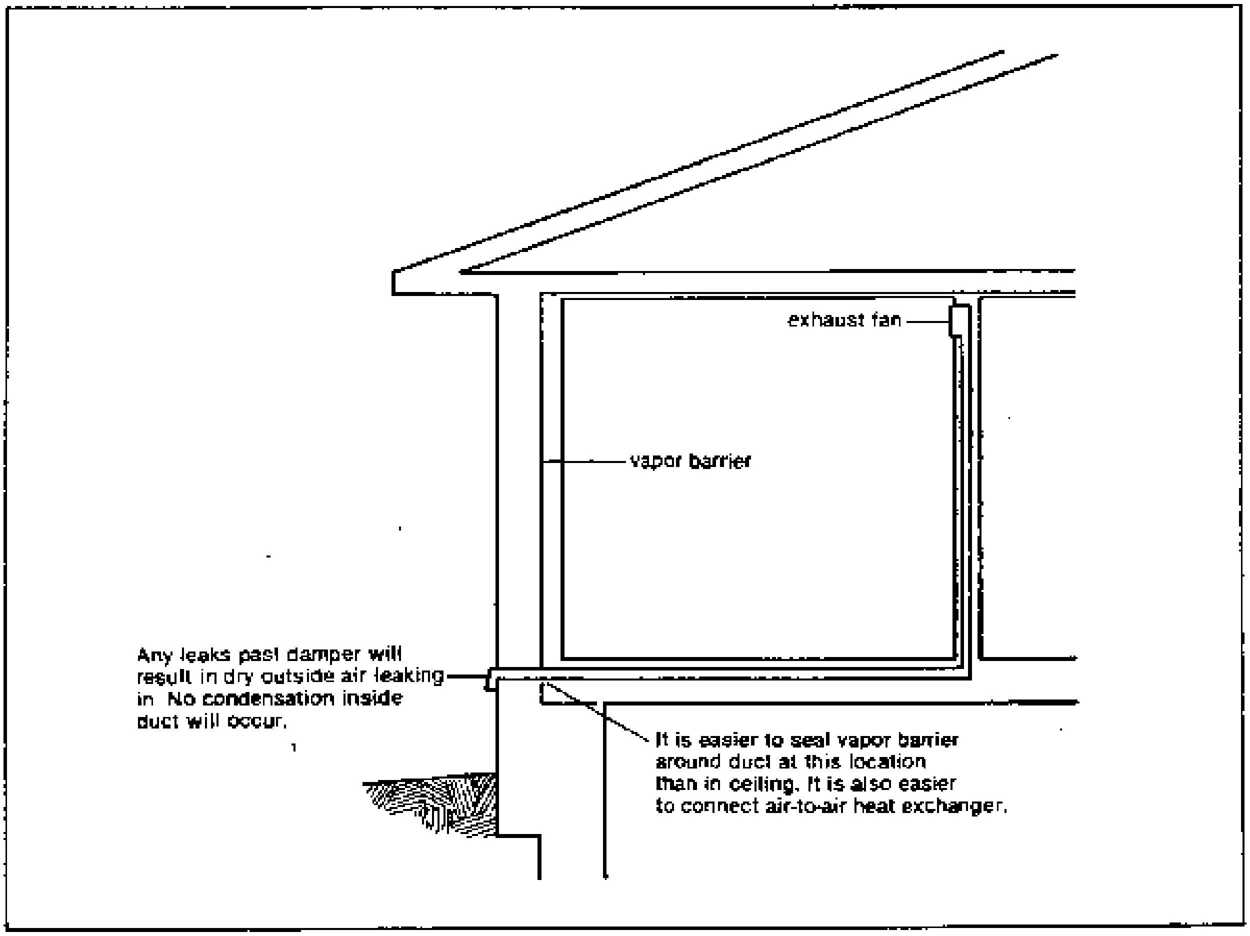


Figure 16. Air-to-air heat exchanger.

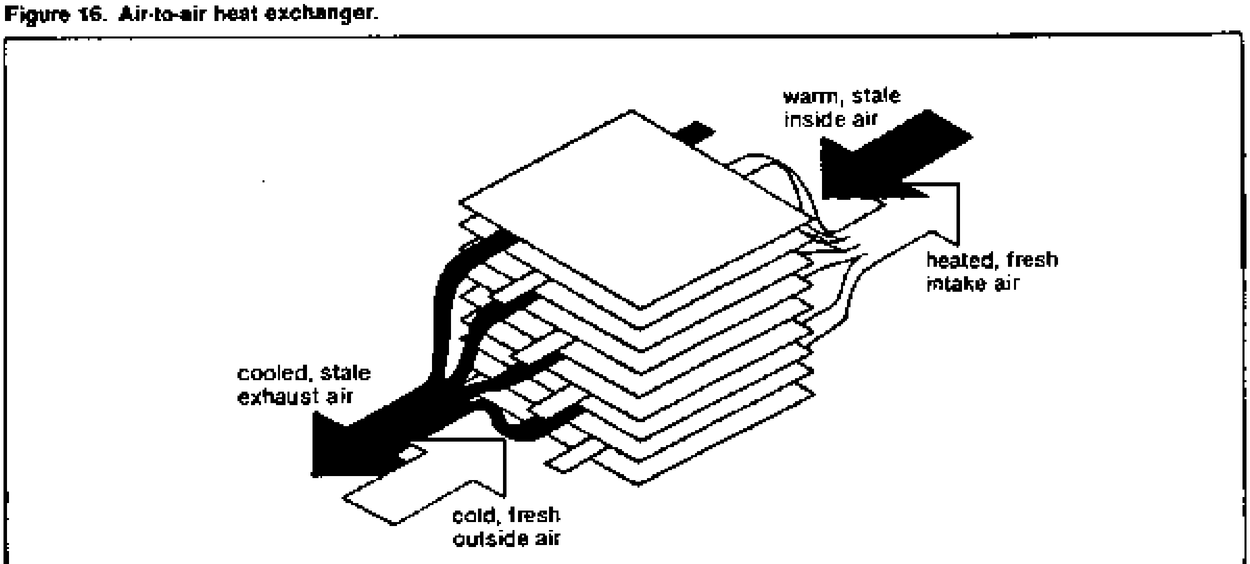


Figure 17. Fully ducted basement installation of a heat exchanger.

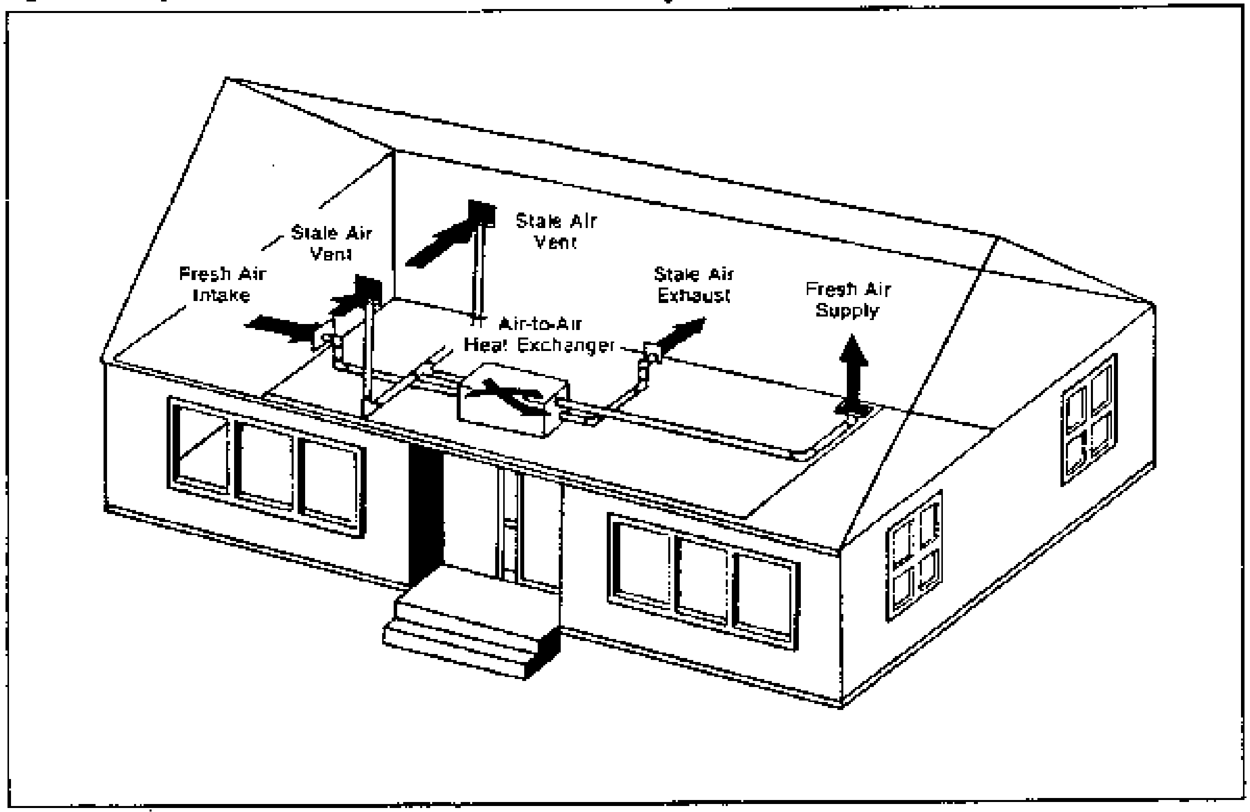


Figure 18. Attic access door.

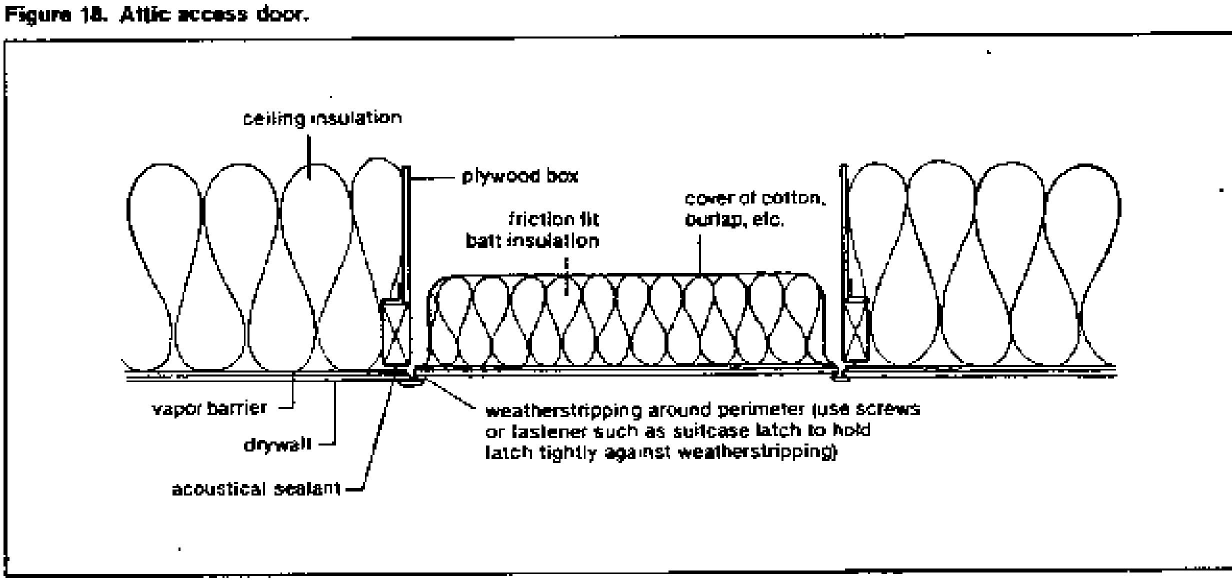


Figure 19. Use of a furnace room to isolate fuel burning equipment from the rest of the house.

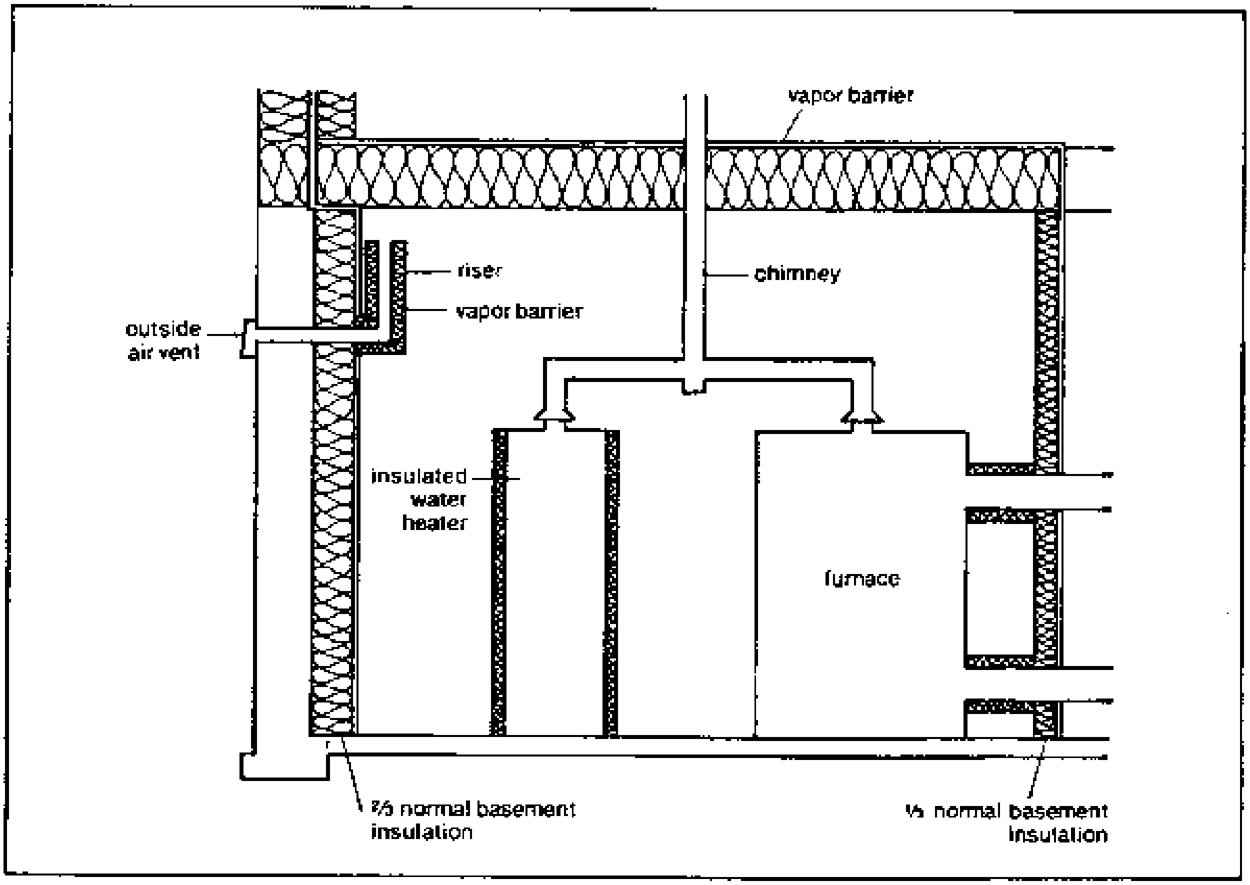


Figure 20. Chimney installation detail.

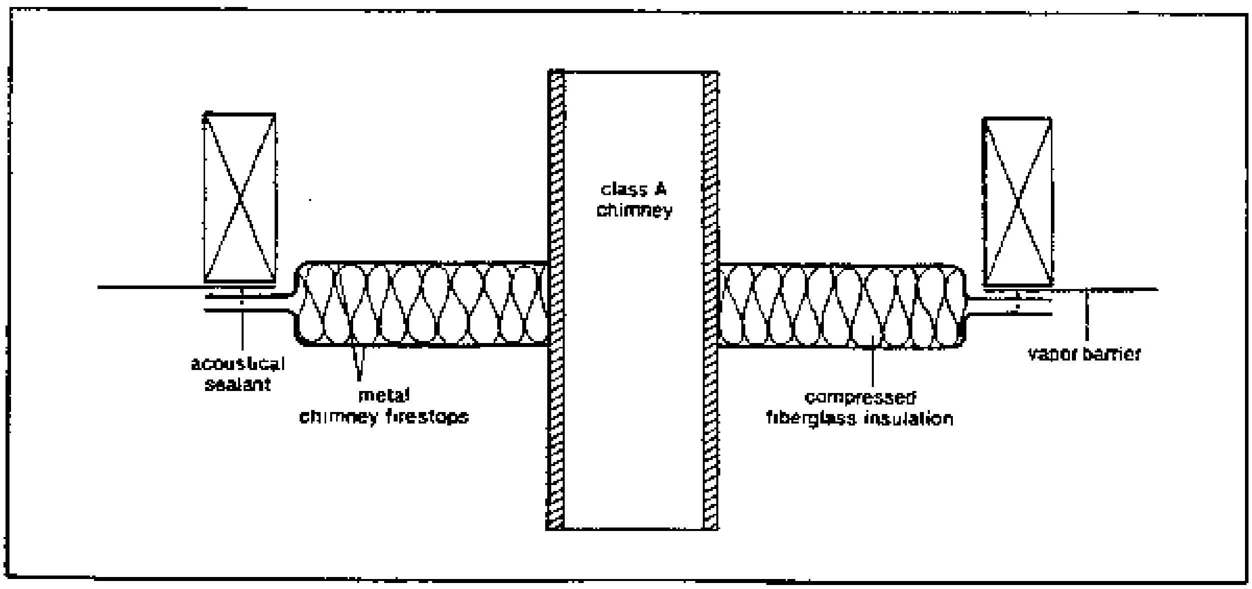


Figure 21. Technique for super-insulating the exterior walls of an existing house.

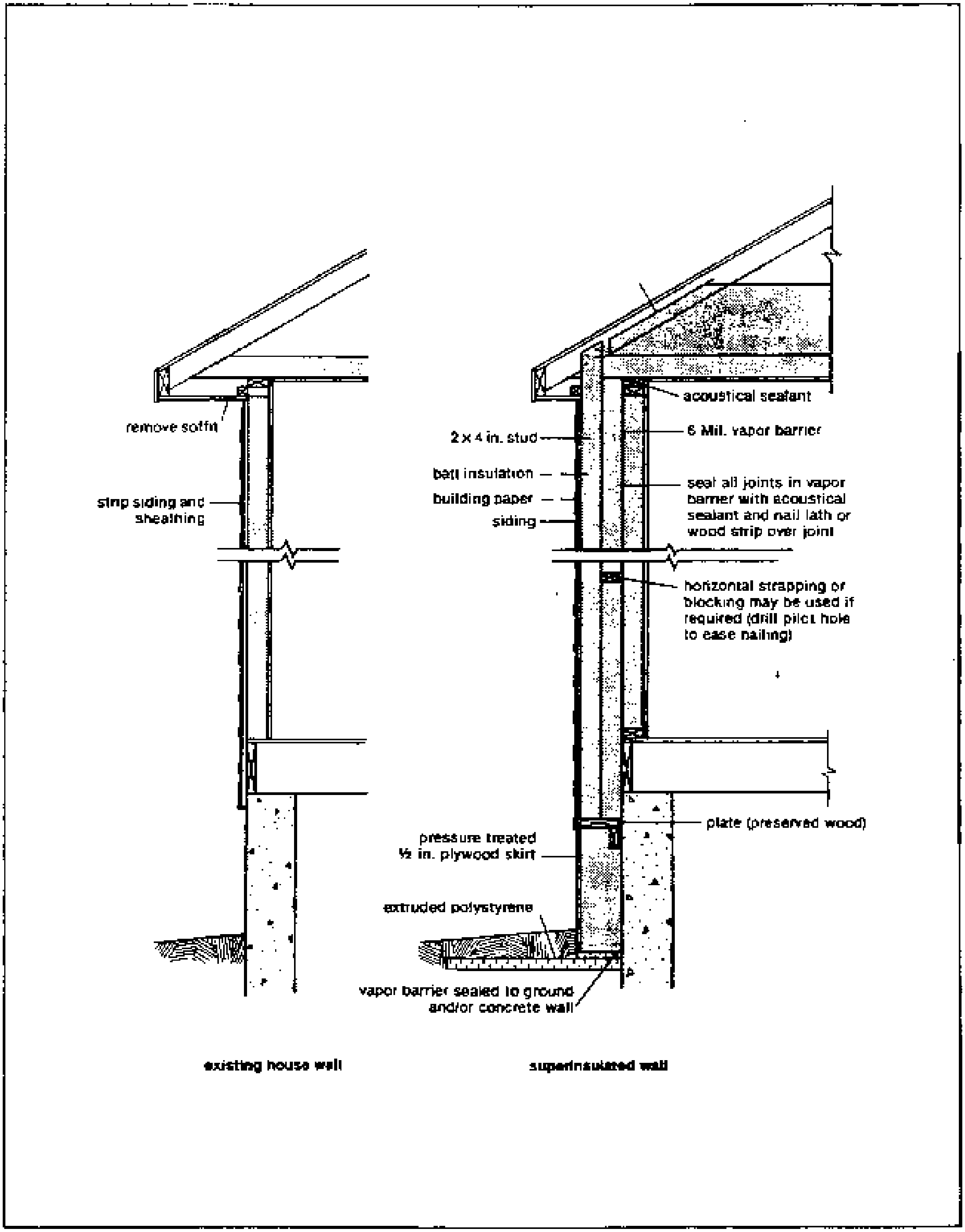
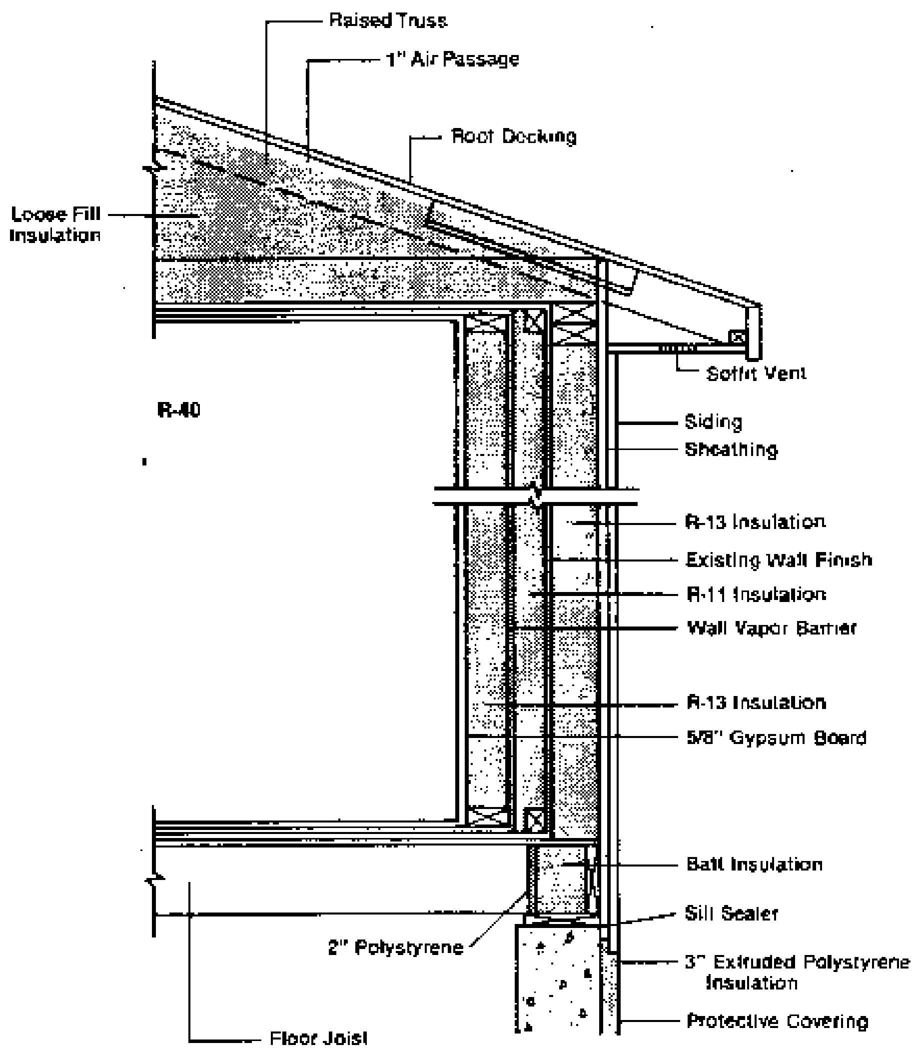


Figure 22. Retrofitting the interior of an existing house with previous 2 × 4 wall.



APPENDIX A

Climatic Data

DESIGN TEMPERATURES

Montana	
Miles City	−19
North Dakota	
Bismarck	−24
Devils Lake	−23
Fargo	−22
Williston	−21

Meteorological Data

Source: National Oceanic and Atmospheric Administration, Environmental Data and Information Service, National Climatic Center, Asheville, NC 38801.

Meteorological Data: Normals, Means, And Extremes

Station: Miles City, Montana   Municipal Airport

Month	Temperatures °F – Normal – Daily maximum	Daily minimum	Monthly	Extremes – Record highest	Year	Record lowest	Year	Normal Degree days Base 65°F – Heating	Cooling	Precipitation in inches – Water Equivalent – Normal	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs.	Year	Snow, Ice pellets – Maximum monthly	Year	Maximum in 24 hrs.	Year
(a)				42		42					42		42		27		39		17	
J	26.1	4.7	15.4	62	1953	-37	1969	1538	0	0.49	1.78	1971	0.08	1961	0.42	1944	17.2	1971	7.5	1964
F	32.0	10.4	21.6	66	1961	-37	1939	1215	0	0.51	1.30	1959	0.08	1954	0.77	1952	19.0	1949	6.5	1952
M	41.6	10.7	30.2	83	1943	-27	1947	1079	0	0.65	1.83	1950	0.07	1959	0.61	1944	17.8	1967	5.0	1957
A	57.8	32.7	45.3	91	1952	7	1954	591	0	1.26	4.22	1973	0.10	1952	1.36	1947	16.6	1967	10.5	1947
M	68.9	43.6	56.3	99	1964	15	1954	288	19	2.06	6.81	1978	0.24	1958	2.39	1955	8.6	1967	2.0	1953
J	77.4	52.3	64.9	104	1961	32	1951	117	114	3.32	9.78	1944	0.77	1979	2.71	1964	2.0	1950	2.0	1950
J	88.9	59.8	74.4	109	1960	41	1945	9	301	1.55	4.58	1948	0.10	1971	2.02	1962	0.0		0.0	
A	87.2	57.7	72.5	110	1949	35	1966	16	248	1.20	4.00	1951	T	1967	1.65	1943	0.0		0.0	
S	73.5	46.2	59.9	105	1950	20	1942	217	64	1.19	4.67	1941	T	1960	2.67	1941	7.1	1972	0.7	1950
O	62.1	35.5	48.8	93	1963	9	1972	508	6	0.71	6.31	1971	T	1965	1.30	1953	12.6	1949	3.8	1946
N	43.1	21.7	32.4	75	1965	-23	1955	978	0	0.51	2.17	1978	0.02	1953	1.18	1957	19.4	1977	8.0	1964
D	32.2	11.7	22.0	69	1939	-35	1977	1333	0	0.48	1.78	1968	0.02	1957	0.50	1941	18.0	1968	7.0	1956
YR	57.6	32.9	45.3	110	AUG 1949	-37	JAN 1969	7889	752	13.93	9.78	JUN 1944	T	AUG 1967	2.71	JUN 1964	19.4	NOV 1977	10.5	APR 1947

Month	Relative humidity pct. – Hour 05	Hour 11 (Local time)	Hour 17	Hour 23	Wind – Mean speed m.p.h.	Prevailing direction	Fastest mile – Speed m.p.h.	Direction	Year	Pct. of possible sunshine	Mean sky cover, tenths, sunrise to sunset	Mean number of days – Sunrise to sunset – Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Ice pellets 1.0 inch or more	Thunderstorms	Heavy fog, visibility ½ mile or less	Temperatures °F – Max. – (b) 90°F and above	32°F and below	Min. – 32°F and below	0°F and below	Average station pressure mb. Elev. 2634 feet m.s.l.
(a)	19	19	19	19	30	14					13	18	18	18	42	30	29	27	35	35	35	35	7
J	74	70	70	74	9.6	NW					6.8	6	8	17	8	2	0	1	0	18	30	13	922.9
F	80	71	69	78	9.8	NW					7.0	5	8	15	7	2	0	2	0	13	28	7	922.0
M	80	63	56	74	10.8	NW					6.9	5	8	18	8	2	*	1	0	7	27	3	918.8
A	79	54	48	69	11.8	NW					6.8	5	8	17	8	1	1	1	*	1	15	0	920.0
M	78	49	44	67	11.1	SE					6.5	6	10	15	11	*	4	1	1	*	2	0	919.3
J	77	47	40	65	10.4	SE					5.5	8	10	12	11	*	8	*	4	0	*	0	919.7
J	69	39	32	54	9.7	SE					4.0	15	12	4	8	0	7	*	15	0	0	0	921.6
A	65	38	29	50	9.7	SE					4.0	15	11	5	7	0	6	*	14	0	0	0	921.4
S	73	48	39	60	9.9	NW					5.1	10	10	10	7	*	2	1	3	0	2	0	922.7
O	74	51	46	65	9.8	SSE					5.4	12	8	11	6	*	*	1	*	*	11	0	922.7
N	78	65	63	74	9.8	SSE					6.6	7	7	16	6	2	*	1	0	7	27	2	923.1
D	77	72	71	76	9.8	SSE					6.5	7	8	16	7	2	*	2	0	15	30	7	921.1
YR	75	55	51	67	10.2	SE					5.9	101	108	156	94	13	28	11	37	61	171	32	921.3

Means and extremes above are from existing and comparable exposures. Annual extremes have been exceeded at other sites in the locality as follows: Highest temperature 111 in July 1901; lowest temperature -49 in February 1899; minimum monthly precipitation 0.00 in August 1889 and earlier; maximum precipitation in 24 hours 3.74 in May 1908; maximum monthly snowfall 35.3 in March 1894; maximum snowfall in 24 hours 28.0 in March 1894.

(a) Length of record, years, through the current year unless otherwise noted, based on January data.
(b) 70° and above at Alaskan stations.
*** Less than one half.**
T Trace.

NORMALS - Based on record for 1941-1970 period.
DATE OF AN EXTREME - The most recent in cases of multiple occurrence.
PREVAILING WIND DIRECTION - Record through 1963.
WIND DIRECTION - Numerals indicate tens of degrees clockwise from true north. 00 indicates calm.
FASTEST MILE WIND - Speed is fastest observed 1-minute value when the direction is in tens of degrees.

$ Greatest in calendar day. Record through 1964.

* Record through 1962.

Meteorological Data: Normals, Means, And Extremes

Station: Bismarck, North Dakota   Municipal Airport   Standard time used: Central

Month	Temperatures °F: Normal: Daily maximum	Normal: Daily minimum	Normal: Monthly	Extremes: Record highest	Year	Record lowest	Year	Normal Degree days Base 65 °F: Heating	Cooling	Precipitation in inches: Water Equivalent: Normal	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs.	Year	Snow, Ice pellets: Maximum monthly	Year	Maximum in 24 hrs.	Year
(a)				40		40					40		40		40		40		40	
J	19.1	-2.8	8.2	54	1961	-44	1950	1761	0	0.51	1.29	1969	0.02	1940	0.67	1952	16.9	1950	7.9	1952
F	24.5	2.4	13.5	68	1958	-37	1971	1442	0	0.44	1.21	1979	0.08	1973	0.73	1958	25.6	1979	8.9	1979
M	35.4	14.7	25.1	81	1946	-31	1948	1237	0	0.73	3.19	1975	0.11	1961	1.30	1950	31.1	1975	15.5	1966
A	54.8	31.1	43.0	92	1952	-12	1975	660	0	1.44	5.45	1975	T	1952	1.97	1964	18.2	1970	8.7	1942
M	67.1	41.7	54.4	98	1941	15	1967	339	11	2.17	5.18	1965	0.31	1952	1.98	1978	10.3	1950	11.0	1967
J	75.8	51.8	63.8	100	1961	30	1969	122	86	3.58	8.29	1947	0.50	1974	3.25	1947	T	1969	T	1969
J	84.3	57.3	70.8	109	1973	35	1971	18	198	2.20	5.24	1968	0.18	1968	2.33	1969	0.0		0.0	
A	83.5	54.9	69.2	109	1941	33	1964	35	165	1.96	5.05	1944	0.03	1971	2.68	1965	0.0		0.0	
S	71.3	43.7	57.5	105	1959	11	1974	252	27	1.32	6.93	1977	0.02	1948	3.02	1977	4.1	1942	4.1	1942
O	60.3	33.2	46.8	95	1963	5	1960	564	0	0.80	3.74	1971	0.05	1968	1.62	1971	7.6	1946	4.9	1946
N	39.4	18.3	28.9	75	1978	-29	1964	1083	0	0.56	2.56	1944	T	1963	0.99	1944	16.6	1978	6.3	1977
D	26.0	5.2	15.6	65	1979	-43	1967	1531	0	0.45	0.95	1967	T	1944	0.59	1960	17.2	1977	7.6	1950
YR	53.5	29.3	41.4	109	JUL 1973	-44	JAN 1950	9044	487	16.16	8.29	JUN 1947	T	NOV 1963	3.25	JUN 1947	31.1	MAR 1975	15.5	MAR 1966

Month	Relative humidity pct.: Hour 05 (Local time)	Hour 11	Hour 17	Hour 23	Wind: Mean speed m.p.h.	Prevailing direction	Fastest mile: Speed m.p.h.	Direction	Year	Pct. of possible sunshine	Mean sky cover, tenths, sunrise to sunset	Mean number of days: Sunrise to sunset: Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Ice pellets 1.0 inch or more	Thunderstorms	Heavy fog, visibility ½ mile or less	Temperatures °F: Max.: (b) 90 °F and above	Max.: 32 °F and below	Min.: 32 °F and below	Min.: 0 °F and below	Average station pressure mb. Elev. 1660 feet m.s.l.
(a)	20	20	20	20	40	14	40	40		40	40	40	40	40	40	40	40	40	20	20	20	20	7
J	72	72	66	68	10.1	WNW	54	NW	1975	55	6.7	7	8	16	8	3	0	1	0	25	31	20	957.6
F	75	75	67	68	10.1	WNW	59	NW	1972	55	6.9	5	8	15	7	2	0	2	0	18	28	12	957.4
M	76	78	62	59	11.1	WNW	65	NW	1941	60	7.0	5	9	17	8	2	*	2	0	11	29	5	953.8
A	72	79	54	50	12.4	WNW	63	W	1955	58	6.9	6	8	16	8	1	1	1	*	1	17	*	954.8
M	72	79	49	45	12.0	SSE	68	NW	1960	63	6.6	6	11	14	10	*	4	*	1	*	4	0	953.0
J	78	84	53	49	10.7	WNW	66	N	1980	65	6.1	8	10	12	12	0	9	1	2	0	*	0	952.7
J	74	83	47	42	9.4	SSE	72	W	1946	76	4.7	12	12	7	9	0	9	1	6	0	0	0	954.9
A	70	82	44	38	9.6	E	72	S	1944	73	4.8	12	11	8	8	0	8	1	8	0	0	0	954.6
S	73	82	49	44	10.1	WNW	68	NW	1959	66	5.4	10	9	11	7	*	3	1	2	0	3	0	955.9
O	71	78	50	50	10.1	WNW	61	W	1959	59	5.8	10	8	13	5	*	1	1	*	1	15	0	956.0
N	76	79	62	65	10.2	WNW	67	NW	1958	45	6.9	6	7	17	6	2	*	1	0	9	29	2	957.1
D	76	77	69	72	9.6	WNW	61	NW	1956	47	6.8	7	7	17	8	2	0	1	0	21	31	13	955.5
YR	74	79	56	54	10.4	WNW	72	W	JUL 1946	62	6.2	94	108	163	96	13	34	12	21	86	186	52	955.3

Means and extremes above are from existing and comparable exposures. Annual extremes have been exceeded at other sites in the locality as follows: Highest temperature 114 in July 1936; lowest temperature -45 in February 1936 and earlier; maximum monthly precipitation 9.90 in June 1914; maximum precipitation in 24 hours 3.76 in June 1914.

(a) Length of record, years, through the current year unless otherwise noted, based on January data.
(b) 70° and above at Alaskan stations.
* Less than one half.
T Trace.

NORMALS - Based on record for 1941-1970 period.
DATE OF AN EXTREME - The most recent in cases of multiple occurrence.
PREVAILING WIND DIRECTION - Record through 1963.
WIND DIRECTION - Numerals indicate tens of degrees clockwise from true north. 00 indicates calm.
FASTEST MILE WIND - Speed is fastest observed 1-minute value when the direction is in tens of degrees.

Meteorological Data: Normals, Means and Extremes

Station: Fargo, North Dakota   Hector Field   Standard time used: Central

Month	Temperatures °F							Normal Degree days Base 65°F		Precipitation in inches										
	Normal			Extremes						Water Equivalent							Snow, Ice pellets			
	Daily maximum	Daily minimum	Monthly	Record highest	Year	Record lowest	Year	Heating	Cooling	Normal	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs.	Year	Maximum monthly	Year	Maximum in 24 hrs.	Year
(a)				27		27					38		38		38		38		38	
J	15.4	-3.6	5.9	49	1958	-35	1977	1832	0	0.50	1.36	1950	0.09	1961	0.68	1949	18.3	1975	7.0	1972
F	20.6	.8	10.7	66	1958	-34	1962	1520	0	0.44	1.74	1979	0.03	1954	1.22	1946	19.5	1979	11.2	1951
M	33.5	14.9	24.2	78	1967	-23	1962	1265	0	0.83	2.21	1950	0.03	1958	1.16	1950	18.7	1975	10.4	1975
A	52.6	31.9	42.3	88	1962	-7	1975	681	0	2.08	4.24	1942	0.02	1949	1.91	1963	12.8	1970	8.6	1970
M	66.8	42.3	54.6	98	1964	20	1966	334	11	2.29	7.30	1977	0.46	1976	4.10	1977	1.0	1950	1.0	1950
J	75.9	53.4	64.7	99	1969	30	1969	97	88	3.20	9.40	1975	0.58	1972	4.02	1975	0.0		0.0	
J	82.8	58.6	70.7	100	1976	36	1967	13	190	3.16	8.42	1952	0.42	1950	3.93	1952	0.0		0.0	
A	81.6	56.8	69.2	106	1976	33	1964	33	163	2.85	8.52	1944	0.38	1969	4.72	1943	0.0		0.0	
S	69.6	46.2	57.9	102	1959	19	1965	234	21	1.84	6.13	1957	0.13	1974	3.97	1957	0.6	1942	0.6	1942
O	58.4	35.5	47.0	93	1963	7	1976	558	0	1.09	4.42	1971	0.08	1952	2.06	1971	8.1	1951	7.8	1951
N	37.2	20.0	28.6	73	1978	-22	1964	1092	0	0.72	4.58	1977	0.04	1967	1.99	1977	24.2	1977	12.6	1977
D	21.9	4.1	13.0	57	1962	-32	1967	1612	0	0.62	2.19	1951	0.04	1958	0.87	1960	20.3	1951	8.0	1967
YR	51.4	30.1	40.8	106	AUG 1976	-35	JAN 1977	9271	473	19.62	9.40	JUN 1975	0.02	APR 1949	4.72	AUG 1943	24.2	NOV 1977	12.6	NOV 1977

Month	Relative humidity pct.				Wind					Pct. of possible sunshine	Mean sky cover, tenths, sunrise to sunset	Mean number of days							Temperatures °F				Average station pressure mb.
	Hour 05	Hour 11	Hour 17	Hour 23			Fastest mile					Sunrise to sunset							Max.		Min.		
	(Local time)				Mean speed m.p.h.	Prevailing direction	Speed m.p.h.	Direction	Year			Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Ice pellets 1.0 inch or more	Thunderstorms	Heavy fog, visibility ¼ mile or less	(b) 90°F and above	32°F and below	32°F and below	0°F and below	Elev. 899 feet m.s.l.
(a)	20	20	20	20	37	14	38	38		37	34	37	37	37	37	37	37	37	20	20	20	20	7
J	73	73	70	71	12.9	SSE	62	SE	1968	51	6.7	6	8	17	9	2	0	1	0	28	31	21	985.6
F	76	75	72	74	12.8	N	56	W	1957	57	6.6	6	7	15	7	2	*	2	0	23	28	14	985.9
M	81	82	72	71	13.4	N	56	N	1960	58	7.0	5	9	17	8	2	*	2	0	14	28	5	981.7
A	77	81	62	58	14.4	N	68	NW	1964	57	6.8	6	9	15	9	1	1	1	0	1	16	*	982.4
M	70	79	52	47	13.4	N	72	NW	1960	58	6.4	7	10	14	10	*	4	*	*	*	5	0	979.9
J	76	82	57	53	12.0	SSE	115	NW	1959	60	6.2	6	11	13	11	0	7	1	2	0	*	0	978.9
J	78	85	55	52	10.8	S	60	S	1965	71	5.0	11	13	7	10	0	8	1	5	0	0	0	981.1
A	76	86	54	49	11.3	SSE	71	NW	1955	68	5.1	11	12	8	9	0	7	1	6	0	0	0	981.3
S	78	85	58	55	12.3	SSE	88	N	1960	60	5.8	9	9	12	8	0	3	1	1	0	2	0	982.4
O	76	82	59	60	12.9	SSE	57	NW	1960	56	6.1	9	8	14	6	*	1	1	*	*	12	0	982.5
N	80	82	70	73	13.2	S	66	N	1956	40	7.2	5	7	18	6	2	*	1	0	10	27	2	983.9
D	77	78	75	76	12.5	S	58	N	1957	43	7.1	6	8	17	8	2	*	2	0	26	31	13	983.4
YR	76	81	63	62	12.6	N	115	NW	JUN 1959	58	6.3	87	111	167	102	12	33	13	14	103	180	56	982.4

Means and extremes above are from existing and comparable exposures. Annual extremes have been exceeded at other sites in the locality as follows: Highest temperature 114 in July 1936; lowest temperature -48 in January 1887; maximum monthly precipitation 9.58 in August 1900; minimum monthly precipitation T in November 1901; maximum precipitation in 24 hours 5.17 in July 1886; maximum monthly snowfall 30.4 in November 1896; maximum snowfall in 24 hours 19.2 in December 1927.

(a) Length of record, years, through the current year unless otherwise noted, based on January data.
(b) 70° and above at Alaskan stations.
* Less than one half.
T Trace.

NORMALS - Based on record for 1941-1970 period.
DATE OF AN EXTREME - The most recent in cases of multiple occurrence.
PREVAILING WIND DIRECTION - Record through 1963.
WIND DIRECTION - Numerals indicate tens of degrees clockwise from true north. 00 indicates calm.
FASTEST MILE WIND - Speed is fastest observed 1-minute value when the direction is in tens of degrees.

Meteorological Data: Normals, Means, And Extremes

Station: Williston, North Dakota   Sloulin Field Int'l Airport   Standard time used: Central

Month	Temperatures °F							Normal Degree days Base 65 °F		Precipitation in inches										
	Normal			Extremes						Water Equivalent							Snow, Ice pellets			
	Daily maximum	Daily minimum	Monthly	Record highest	Year	Record lowest	Year	Heating	Cooling	Normal	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs.	Year	Maximum monthly	Year	Maximum in 24 hrs.	Year
(a)				18		18					18		18		18		18		18	
J	19.3	-2.8	8.3	50	1968	-40	1966	1758	0	0.59	1.42	1967	0.03	1973	0.49	1976	16.6	1967	8.4	1976
F	25.7	2.6	14.2	55	1973	-41	1962	1422	0	0.53	1.48	1967	0.10	1970	0.43	1962	16.5	1972	4.3	1962
M	35.6	13.8	24.7	78	1978	-28	1962	1249	0	0.63	2.26	1975	0.01	1966	0.88	1975	30.9	1975	9.3	1975
A	54.9	29.9	42.4	90	1962	-15	1975	678	0	1.24	3.31	1967	0.38	1962	2.04	1967	22.2	1970	7.6	1970
M	67.0	41.1	54.1	98	1964	20	1976	345	7	1.62	7.38	1965	0.18	1967	2.05	1965	1.4	1965	1.4	1965
J	75.0	50.4	62.7	103	1979	30	1969	135	66	3.25	5.92	1964	0.91	1967	2.20	1964	0.0		0.0	
J	84.0	56.1	70.1	107	1966	34	1967	22	180	2.04	6.20	1963	0.49	1976	5.03	1963	0.0		0.0	
A	82.8	54.1	68.5	103	1969	36	1964	35	144	1.56	3.38	1968	0.07	1971	2.45	1972	0.0		0.0	
S	70.3	43.1	56.7	102	1978	17	1974	274	25	1.21	3.06	1973	0.11	1963	2.24	1971	3.0	1972	3.0	1972
O	58.9	32.5	45.7	93	1963	3	1972	598	0	0.64	3.56	1971	T	1965	2.21	1971	5.0	1962	5.0	1962
N	38.3	17.8	28.1	71	1975	-23	1964	1107	0	0.53	1.14	1975	0.04	1969	0.80	1974	14.1	1975	7.9	1975
D	25.8	5.0	15.4	58	1979	-37	1977	1538	0	0.49	1.28	1964	0.09	1979	0.68	1975	15.2	1978	10.1	1978
YR	53.1	28.6	40.9	107	JUL 1966	-41	FEB 1962	9161	422	14.33	7.38	MAY 1965	T	OCT 1965	5.03	JUL 1963	30.9	MAR 1975	10.1	DEC 1978

Month	Relative humidity pct.				Wind					Pct. of possible sunshine	Mean sky cover, tenths, sunrise to sunset	Mean number of days												Average station pressure mb.
	Hour	Hour	Hour	Hour			Fastest mile					Sunrise to sunset							Temperatures °F					
																			Max.		Min.			Elev. 1905
	06	11	17	23	Mean speed m.p.h.	Prevailing direction	Speed m.p.h.	Direction	Year			Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Ice pellets 1.0 inch or more	Thunderstorms %	Heavy fog, visibility ¼ mile or less %	(b) 90°F and above	32°F and below	32°F and below	0°F and below	feet m.s.l.
	(Local time)																							
(a)	12	18	18	18	15	3	18	18		17	18	18	18	18	18	18	15	15	18	18	18	18	7
J	79	78	72	74	9.9	W	70	NW	1964	50	7.0	5	9	17	9	2	0	*	0	24	31	20	946.4
F	81	81	72	73	9.9	NE	66	NW	1965	56	7.0	5	7	16	7	2	0	1	0	18	28	12	947.8
M	80	83	66	63	10.3	NW	52	NW	1967	61	6.6	7	8	16	8	2	0	1	0	11	29	5	944.5
A	75	82	56	52	11.4	SE	56	SW	1962	56	7.0	5	9	16	9	2	1	1	*	1	19	*	946.0
M	71	79	49	44	11.2	SE	56	NW	1963	61	6.7	5	11	15	10	0	3	*	1	0	4	0	944.1
J	72	83	50	45	10.1	SE	61	NW	1963	66	6.1	7	11	12	11	0	8	*	2	0	*	0	943.8
J	70	82	46	39	9.3	SE	64	NW	1966	75	4.8	11	13	7	9	0	8	*	7	0	0	0	946.3
A	65	79	44	36	9.6	SW	47	W	1967	75	4.9	12	11	8	6	0	5	*	8	0	0	0	946.0
S	70	81	51	44	10.0	SW	50	NW	1962	65	5.6	9	9	12	7	*	2	1	2	0	3	0	947.2
O	72	79	54	51	10.2	SW	57	N	1962	59	6.2	9	7	15	5	*	0	1	*	1	15	0	946.9
N	79	81	67	70	9.3	SW	47	NW	1962	43	6.9	6	8	16	6	2	0	2	0	10	29	4	948.1
D	81	80	73	76	9.7	SW	56	W	1964	46	6.8	7	7	17	8	2	0	1	0	21	31	13	946.0
YR	75	81	58	55	10.1	SW	70	NW	JAN 1964	61	6.3	88	110	167	94	12	27	9	19	86	190	54	946.3

Means and extremes above are from existing and comparable exposures. Annual extremes have been exceeded at other sites in the locality as follows: Highest temperature 110 in July 1936; lowest temperature -50 in February 1936; maximum monthly precipitation 8.84 in June 1901; maximum snowfall in 24 hours 10.6 in April 1947.

(a) Length of record, years, through the current year unless otherwise noted, based on January data.
(b) 70° and above at Alaskan stations.
* Less than one half.
T Trace.

NORMALS - Based on record for 1941-1970 period.
DATE OF AN EXTREME - The most recent in cases of multiple occurrence.
PREVAILING WIND DIRECTION - Record through 1963.
WIND DIRECTION - Numerals indicate tens of degrees clockwise from true north. 00 indicates calm.
FASTEST MILE WIND - Speed is fastest observed 1-minute value when the direction is in tens of degrees.

% Based on available record. The station did not operate 24 hours daily prior to March 1967.

Meteorological Data: Normals, Means, And Extremes

Station: Aberdeen, South Dakota Regional Airport Standard time used: Central

Month	Temperatures °F: Normal: Daily maximum	Daily minimum	Monthly	Extremes: Record highest	Year	Record lowest	Year	Normal Degree days Base 65 °F: Heating	Cooling	Precipitation in inches: Water Equivalent: Normal	Maximum monthly	Year	Minimum monthly	Year	Maximum in 24 hrs.	Year	Snow, Ice pellets: Maximum monthly	Year	Maximum in 24 hrs.	Year
(a)				20		20					50		50		50		50		50	
J	20.5	-1.5	9.5	55	1963	-35	1972	1720	0	0.53	2.23	1937	0.01	1961	1.12	1939	26.2	1937	10.0	1937
F	26.0	4.1	15.1	62	1976	-37	1971	1397	0	0.63	2.06	1952	0.00	1932	1.02	1958	25.1	1969	14.3	1951
M	37.7	16.6	27.2	82	1963	-29	1962	1172	0	0.94	3.45	1977	0.04	1971	3.00	1937	27.9	1975	13.0	1937
A	56.7	31.7	44.2	97	1962	-2	1975	624	0	1.96	5.13	1953	0.33	1952	2.28	1938	24.4	1970	15.0	1970
M	68.6	42.8	55.7	96	1969	19	1961	303	15	2.57	6.36	1949	0.28	1948	3.61	1949	2.0	1943	2.0	1943
J	77.4	53.4	65.4	103	1963	33	1964	93	105	3.63	8.88	1939	0.37	1974	5.20	1978	0.0		0.0	
J	85.1	58.4	71.8	110	1966	39	1971	12	223	2.74	7.71	1972	0.30	1975	3.09	1974	0.0		0.0	
A	84.7	56.4	70.6	112	1965	35	1965	21	195	2.10	6.62	1942	0.06	1947	2.72	1930	0.0		0.0	
S	73.2	45.1	59.2	103	1970	20	1965	202	28	1.71	4.51	1941	0.05	1979	2.60	1967	0.1	1965	0.1	1965
O	61.9	33.9	47.9	96	1963	11	1976	530	0	1.22	3.27	1946	0.00	1952	2.00	1944	5.5	1970	5.0	1932
N	41.4	19.4	30.4	78	1975	-27	1964	1038	0	0.62	2.36	1977	0.01	1976	1.30	1977	24.7	1936	9.0	1953
D	26.9	6.1	16.5	62	1969	-39	1967	1504	0	0.45	1.86	1935	T	1943	0.90	1935	18.5	1935	8.0	1935
YR	55.0	30.5	42.8	112	AUG 1965	-39	DEC 1967	8616	566	19.10	8.88	JUN 1939	0.00	OCT 1952	5.20	JUN 1978	27.9	MAR 1975	15.0	APR 1970

Month	Relative humidity pct.: Hour 05	Hour 11 (Local time)	Hour 17	Hour 23	Wind: Mean speed m.p.h.	Prevailing direction	Fastest mile: Speed m.p.h.	Direction	Year	Pct. of possible sunshine	Mean sky cover, tenths, sunrise to sunset	Mean number of days: Sunrise to sunset: Clear	Partly cloudy	Cloudy	Precipitation .01 inch or more	Snow, Ice pellets 1.0 inch or more	Thunderstorms	Heavy fog, visibility ¼ mile or less	Temperatures °F: Max.: (b) 90°F and above	32°F and below	Min.: 32°F and below	0°F and below	Average station pressure mb. Elev. 1300 feet m.s.l.
(a)	13	13	15	15	13		13	13			15	15	15	15	50	50	13	13	20	20	20	20	6
J	73	73	69	71	11.4		58	34	1967		6.3	8	7	16	7	3	0	2	0	25	31	18	971.0
F	76	76	70	72	11.6		52	06	1967		6.7	6	7	15	6	2	0	2	0	18	28	11	970.5
M	79	81	67	65	12.5		52	35	1966		6.9	6	8	17	7	2	*	2	0	11	28	4	966.4
A	75	82	58	54	13.2		49	36	1968		7.0	6	6	18	8	1	2	1	*	*	15	*	967.2
M	72	80	52	48	12.4		46	16	1965		6.4	7	10	14	10	*	5	*	*	0	4	0	965.6
J	77	84	56	52	10.6		43	19	1967		5.7	9	10	11	10	0	9	1	3	0	0	0	965.2
J	75	83	52	47	9.6		58	32	1973		4.7	12	13	6	8	0	9	1	10	0	0	0	967.3
A	72	84	48	43	10.3		38	14	1969		4.7	12	11	8	8	0	6	1	9	0	0	0	967.2
S	74	83	51	47	10.6		41	32	1977		5.1	12	8	10	6	0	3	1	2	0	2	0	968.7
O	74	81	53	54	11.1		37	33	1968		5.8	10	8	13	5	*	1	1	*	*	14	0	966.7
N	80	82	68	70	10.9		41	36	1975		6.9	6	7	17	5	2	0	3	0	8	28	2	969.5
D	80	80	72	75	10.7		40	36	1972		6.8	7	7	17	6	2	0	3	0	21	31	11	969.1
YR	76	81	60	58	11.2		58	32	JUL 1973		6.1	101	102	162	87	12	36	18	25	84	180	46	968.8

Means and extremes above are from existing and comparable exposures. Annual extremes have been exceeded at other sites in the locality as follows: Highest temperature 115 in July 1936; lowest temperature -46 in January 1912.

(a) Length of record, years, through the current year unless otherwise noted, based on January data.
(b) 70° and above at Alaskan stations.
*** Less than one half.**
T Trace.

NORMALS - Based on record for 1941-1970 period.
DATE OF AN EXTREME - The most recent in cases of multiple occurrence.
PREVAILING WIND DIRECTION - Record through 1963.
WIND DIRECTION - Numerals indicate tens of degrees clockwise from true north. 00 indicates calm.
FASTEST MILE WIND - Speed is fastest observed 1-minute value when the direction is in tens of degrees.

$ Per observational day prior to 1946.

* through 1977.

Solar Insolation

TABLE OF MONTHLY AVERAGE SOLAR RADIATION, TEMPERATURE, AND DEGREE-DAYS

HS = normal daily value of total hemispheric solar radiation on a horizontal surface (Btu/ft^2 day).

VS = normal daily value of total solar radiation on a vertical, south-facing surface (Btu/ft^2 day).

TA = (Tmin + Tmax)/2, where Tmin and Tmax are monthly (or annual) normals of daily minimum and maximum ambient temperature (F).

Dxx = monthly (or annual) normal of heating degree-days below the base temperature xx (°F-days).

"Normals" are mean values for the period 1941 to 1970. Degree-days from base temperatures other than 65 F were calculated.

MILES CITY, MONTANA LAT = 46.4 ELEV = 2634

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
HS	457	745	1185	1542	1896	2146	2293	1977	1444	961	551	389	1300
VS	947	1232	1469	1351	1248	1231	1389	1517	1557	1436	1072	877	15327
TA	15.4	21.6	30.2	45.3	56.3	64.9	74.4	72.5	59.9	48.8	32.4	22.0	45.3
D50	1073	795	615	190	37	5	1	1	18	134	531	868	4265
D55	1228	935	769	308	95	16	2	3	47	230	679	1023	5334
D60	1383	1075	924	446	177	47	6	9	111	359	828	1178	6544
D65	1538	1215	1079	591	288	117	9	16	217	508	978	1333	7889
D70	1693	1355	1234	741	432	199	54	78	318	656	1128	1488	9378

MINOT, NORTH DAKOTA LAT = 48.3 ELEV = 1713

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
HS	384	656	1044	1461	1846	1975	2098	1800	1277	850	438	310	1178
VS	841	1143	1384	1353	1289	1200	1348	1463	1453	1338	900	721	14413
TA	7.9	12.8	23.6	41.1	52.8	62.0	68.6	67.2	56.2	46.1	27.9	14.7	40.1
D50	1305	1042	819	280	60	6	1	1	26	168	663	1094	5465
D55	1460	1182	973	420	136	21	4	6	79	289	813	1249	6633
D60	1615	1322	1128	568	244	68	14	21	160	434	963	1404	7943
D65	1770	1462	1283	717	384	150	27	70	286	586	1113	1559	9407
D70	1925	1602	1438	867	535	257	119	147	418	741	1263	1714	11025

BISMARCK, NORTH DAKOTA LAT = 46.8 ELEV = 1647

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
HS	487	776	1168	1459	1848	2060	2184	1877	1364	908	507	373	1248
VS	979	1279	1464	1293	1232	1196	1340	1458	1477	1371	987	830	14935
TA	8.2	13.5	25.1	43.0	54.4	63.8	70.8	69.2	57.5	46.8	28.9	15.6	41.4
D50	1296	1022	772	230	40	3	0	1	18	152	633	1066	5235
D55	1451	1162	927	365	108	13	2	3	60	270	783	1221	6364
D60	1606	1302	1082	511	204	45	8	12	135	413	933	1376	7627
D65	1761	1442	1237	660	339	122	18	35	252	564	1083	1531	9044
D70	1916	1582	1392	810	486	211	86	111	380	719	1233	1686	10612

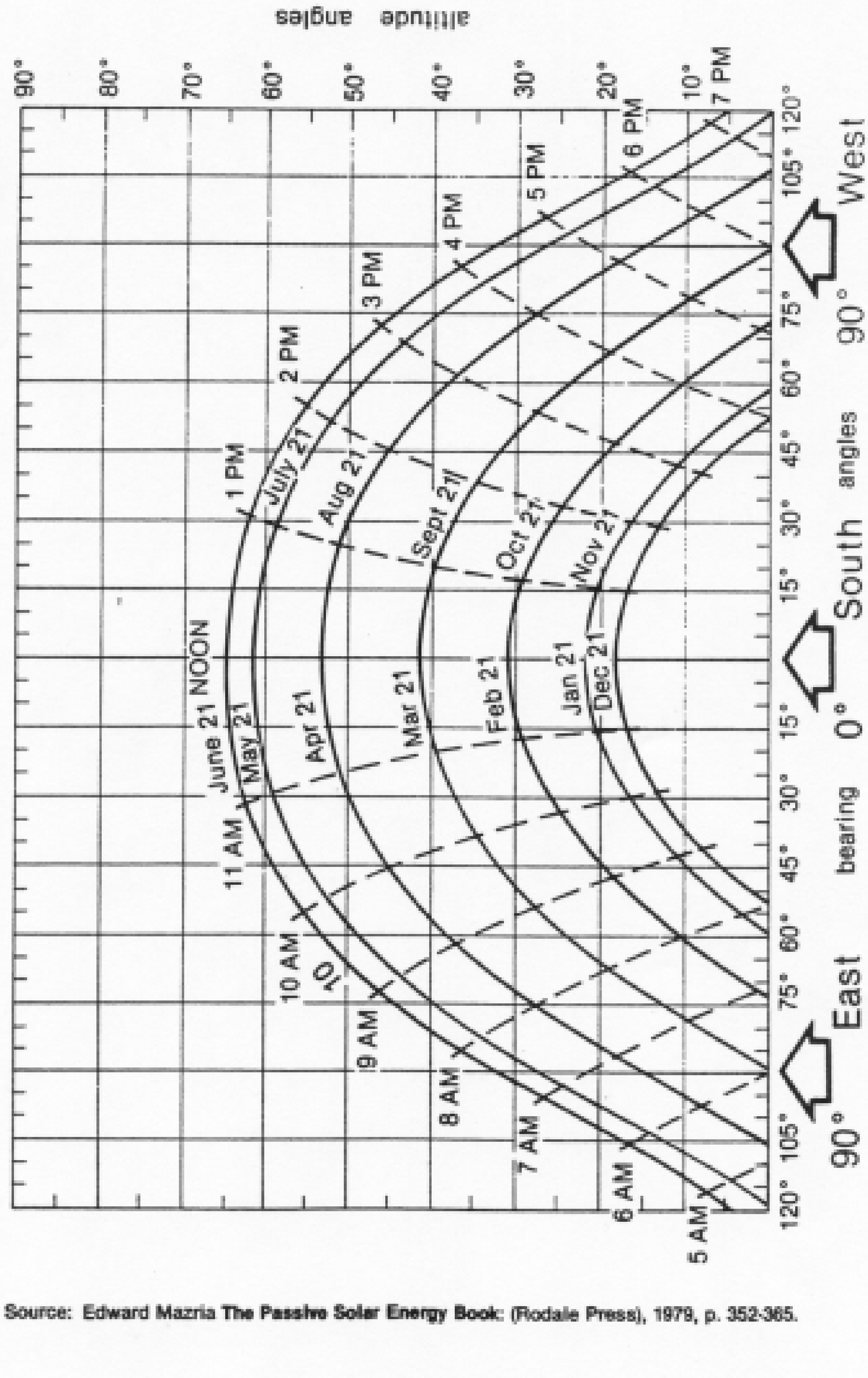
FARGO, NORTH DAKOTA LAT = 46.9 ELEV = 899

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
HS	415	706	1098	1476	1835	1994	2120	1825	1304	874	457	337	1203
VS	873	1184	1380	1312	1227	1161	1304	1422	1426	1324	902	752	14267
TA	5.8	10.7	24.2	42.3	54.6	64.7	70.7	69.2	57.9	47.0	28.6	13.0	40.8
D50	1367	1100	800	243	31	1	0	0	12	140	642	1147	5485
D55	1522	1240	955	384	95	7	1	2	47	260	792	1302	6607
D60	1677	1380	1110	532	192	29	5	8	120	406	942	1457	7858
D65	1832	1520	1265	681	334	97	13	33	234	558	1092	1612	9271
D70	1987	1660	1420	831	479	164	78	102	366	713	1242	1767	10829

Source: J. Douglas Balcomb, et al. Passive Solar Design Handbook Vol. 2: Passive Solar Design Analysis: (Los Alamos Scientific Laboratory: U.S. Dept. of Energy), 1980.

Shading Charts

48° NL



Source: Edward Mazria **The Passive Solar Energy Book**: (Rodale Press), 1979, p. 352-365.

APPENDIX B. Insulation Values

Insulating Values of Construction Materials

1. Conductivities (k), Conductances (C) and Resistances (R) of Building and Insulating Materials

(The constants are expressed in Btu/hr-sq ft-°F. Conductivities are per inch thickness, and Conductances are for thickness or construction stated, but not per inch thickness. All values are for a mean temperature of 75°F, except as noted by an (*) which have been reported at 45°F.)

Description	Density (lb/ft³)	Conductivity (k)	Conductance (C)	Resistance[1] (R) Per inch thickness (1/k)	Resistance[1] (R) For thickness listed (1/C)	Specific Heat, Btu/(lb) (deg F)
Building Board						
Boards, Panels, Subflooring, Sheathing, Woodboard Panel Products						
Asbestos-cement board	120	4.00	—	0.25	—	0.24
Asbestos-cement board ... 0.125 in.	120	—	33.00	—	0.03	
Asbestos-cement board ... 0.25 in.	120	—	16.50	—	0.06	
Gypsum or plaster board ... 0.375 in.	50	—	3.10	—	0.32	0.26
Gypsum or plaster board ... 0.5 in.	50	—	2.22	—	0.45	
Gypsum or plaster board ... 0.625 in.	50	—	1.78	—	0.56	
Plywood (Douglas fir)	34	0.80	—	1.25	—	0.29
Plywood (Douglas fir) ... 0.25 in.	34	—	3.20	—	0.31	
Plywood (Douglas fir) ... 0.375 in.	34	—	2.13	—	0.47	
Plywood (Douglas fir) ... 0.5 in.	34	—	1.60	—	0.62	
Plywood (Douglas fir) ... 0.625 in.	34	—	1.29	—	0.77	
Plywood or wood panels ... 0.75 in.	34	—	1.07	—	0.93	0.29
Vegetable fiber board						
Sheathing, regular density ... 0.5 in.	18	—	0.76	—	1.32	0.31
... 0.78125 in.	18	—	0.49	—	2.06	
Sheathing, intermediate density ... 0.5 in.	22	—	0.82	—	1.22	0.31
Nail-base sheathing ... 0.5 in.	25	—	0.88	—	1.14	0.31
Shingle backer ... 0.375 in.	18	—	1.06	—	0.94	0.31
Shingle backer ... 0.3125 in.	18	—	1.28	—	0.78	
Sound deadening board ... 0.5 in.	15	—	0.74	—	1.35	0.30
Tile and lay-in panels, plain or acoustic ... 0.5 in.	18	—	0.80	—	1.25	
... 0.75 in.	18	—	0.53	—	1.89	
Laminated paperboard	30	0.50	—	2.00	—	0.33
Homogeneous board from repulped paper	30	0.50	—	2.00	—	0.28
Hardboard						
Medium density	50	0.73	—	1.37	—	0.31
High density, service temp. service underlay	55	0.82	—	1.22	—	0.32
High density, std. tempered	63	1.00	—	1.00	—	0.32
Particleboard						
Low density	37	0.54	—	1.85	—	0.31
Medium density	50	0.94	—	1.06	—	0.31
High density	62.5	1.18	—	0.85	—	0.31
Underlayment ... 0.625 in.	40	—	1.22	—	0.82	0.29
Wood subfloor ... 0.75 in.		—	1.06	—	0.94	0.33
Building Membrane						
Vapor—permeable felt	—	—	16.70	—	0.06	
Vapor—seal, 2 layers of mopped 15-lb felt	—	—	8.35	—	0.12	
Vapor-seal, plastic film	—	—	—	—	Negl.	
Finish Flooring Materials						
Carpet and fibrous pad	—	—	0.48		2.08	0.34
Carpet and rubber pad	—	—	0.81		1.23	0.33
Cork tile ... 0.125 in.	—	—	3.60	—	0.28	0.48
Terrazzo ... 1 in.	—	—	12.50	—	0.08	0.19
Tile—asphalt, linoleum, vinyl, rubber	—	—	20.00	—	0.05	0.30
vinyl asbestos						0.24
ceramic						0.19
Wood, hardwood finish ... 0.75 in.			1.47		0.68	
Insulating Materials						
Blanket and Batt						
Mineral fiber, fibrous form processed from rock, slag, or glass						
approx.[4] 2-2.75 in.	0.3-2.0	—	0.143	—	7	0.17-0.2
approx.[4] 3-3.5 in.	0.3-2.0	—	0.091	—	11	
approx.[4] 3.5-6.5 in.	0.3-2.0	—	0.053	—	19	
approx.[4] 6-7 in.	0.3-2.0		0.045		22	
approx.[4] 8.5 in.	0.3-2.0		0.033		30	

Description	Density (lb/ft³)	Conductivity (k)	Conductance (C)	Resistance[1] (R) Per inch thickness (1/k)	Resistance[1] (R) For thickness listed (1/C)	Specific Heat, Btu/(lb) (deg F)
Board and Slabs						
Cellular glass	8.5	0.38	—	2.63	—	0.24
Glass fiber, organic bonded	4-9	0.25	—	4.00	—	0.23
Expanded rubber (rigid)	4.5	0.22	—	4.55	—	0.40
Expanded polystyrene extruded						
Cut cell surface	1.8	0.25		4.00		0.29
Expanded polystyrene extruded						
Smooth skin surface	2.2	0.20		5.00		0.29
Expanded polystyrene extruded						
Smooth skin surface	3.5	0.19	—	5.26	—	
Expanded polystyrene, molded beads	1.0	0.28	—	3.57	—	0.29
Expanded polyurethane[1] (R-11 exp.)	1.5	0.16	—	6.25	—	0.38
(thickness 1 in. or greater)	2.5					
Mineral fiber with resin binder	15	0.29		3.45		
Mineral fiberboard, wet felted						
Core or roof insulation	16-17	0.34	—	2.94	—	
Acoustical tile	18	0.35	—	2.86	—	
Acoustical tile	21	0.37	—	2.70		
Mineral fiberboard, wet molded						
Acoustical tile[2]	23	0.42		2.38		
Wood or cane fiberboard						
Acoustical tile[2] 0.5 in.	—	—	0.80	—	1.25	0.31
Acoustical tile[2] 0.75 in.	—	—	0.53	—	1.89	
Interior finish (plank, tile)	15	0.35	—	2.86	—	0.32
Wood shredded (cemented in preformed slabs)	22	0.60	—	1.67	—	0.31
Loose Fill						
Cellulosic insulation (milled paper or wood pulp)	2.3-3.2	0.27-0.32	—	3.13-3.70	—	0.33
Sawdust or shavings	8.0-15.0	0.45	—	2.22	—	0.33
Wood fiber, softwoods	2.0-3.5	0.30	—	3.33	—	0.33
Perlite, expanded	5.0-8.0	0.37	—	2.70	—	0.26
Mineral fiber (rock, slag or glass)						
approx.[3] 3.75-5 in.	0.6-2.0	—	—		11	0.17
approx.[3] 6.5-8.75 in.	0.6-2.0	—	—		19	
approx.[3] 7.5-10 in.	0.6-2.0	—	—		22	
approx.[3] 10.25-13.75 in.	0.6-2.0	—	—		30	
Vermiculite, exfoliated	7.0-8.2	0.47	—	2.13	—	3.20
	4.0-6.0	0.44		2.27	—	
Roof Insulation[4]						
Preformed, for use above deck. Different roof insulations are available in different thicknesses to provide the design C values listed.[4] Consult individual manufacturers for actual thickness of their material.			0.72 to 0.12		1.39 to 8.33	
Masonry Materials						
Concretes						
Cement mortar	116	5.0		0.20		
Gypsum-fiber concrete 87.5% gypsum, 12.5% wood chips	51	1.66	—	0.60	—	0.21
Lightweight aggregates including expanded	120	5.2	—	0.19	—	
shale, clay, or slate; expanded	100	3.6	—	0.28	—	
slags; cinders; pumice; vermiculite;	80	2.5	—	0.40	—	
also cellular concretes	60	1.7	—	0.59	—	
	40	1.15	—	0.86	—	
	30	0.90	—	1.11	—	
	20	0.70		1.43		
Perlite, expanded	40	0.93		1.08		
	30	0.71		1.41		
	20	0.50		2.00		0.32
Sand and gravel or stone aggregate (oven dried)	140	9.0	—	0.11		0.22
Sand and gravel or stone aggregate (not dried)	140	12.0	—	0.08		
Stucco	116	5.0	—	0.20		
Masonry Units						
Brick, common[5]	120	5.0	—	0.20	—	0.19
Brick, face[5]	130	9.0	—	0.11	—	

Description	Density (lb/ft³)	Conductivity (k)	Conductance (C)	Resistance[a] (R) Per inch thickness (1/k)	For thickness listed (1/C)	Specific Heat, Btu/(lb) (deg F)
Masonry Units (continued)						
Clay tile, hollow:						
1 cell deep ... 3 in.	—	—	1.25	—	0.80	0.21
1 cell deep ... 4 in.	—	—	0.90	—	1.11	
2 cells deep ... 6 in.	—	—	0.66	—	1.52	
2 cells deep ... 8 in.	—	—	0.54	—	1.85	
2 cells deep ... 10 in.	—	—	0.45	—	2.22	
3 cells deep ... 12 in.	—	—	0.40	—	2.50	
Concrete blocks, three oval core:						
Sand and gravel aggregate ... 4 in.	—	—	1.40	—	0.71	0.22
... 8 in.	—	—	0.90	—	1.11	
... 12 in.	—	—	0.78	—	1.28	
Cinder aggregate ... 3 in.	—	—	1.16	—	0.86	0.21
... 4 in.	—	—	0.90	—	1.11	
... 8 in.	—	—	0.58	—	1.72	
... 12 in.	—	—	0.53	—	1.89	
Lightweight aggregate ... 3 in.	—	—	0.79	—	1.27	0.21
(expanded shale, clay, slate ... 4 in.	—	—	0.67	—	1.50	
or slag, pumice) ... 8 in.	—	—	0.50	—	2.00	
... 12 in.	—	—	0.44	—	2.27	
Concrete blocks, rectangular core**						
Sand and gravel aggregate						
2 core, 8 in. 36 lb** ...	—	—	0.96	—	1.04	0.22
Same with filled cores** ...	—	—	0.52	—	1.93	0.22
Lightweight aggregate (expanded shale, clay, slate or slag, pumice)						
3 core, 6 in. 19 lb** ...	—	—	0.61	—	1.65	0.21
Same with filled cores** ...	—	—	0.33	—	2.99	
2 core, 8 in. 24 lb** ...	—	—	0.46	—	2.18	
Same with filled cores** ...	—	—	0.20	—	5.03	
3 core, 12 in. 38 lb** ...	—	—	0.40	—	2.48	
Same with filled cores** ...	—	—	0.17	—	5.82	
Stone, lime or sand ...	—	12.50	—	0.08	—	0.19
Gypsum, partition tile:						
3 × 12 × 30 in. solid ...	—	—	0.79	—	1.26	0.19
3 × 12 × 30 in. 4-cell ...	—	—	0.74	—	1.35	
4 × 12 × 30 in. 3-cell ...	—	—	0.60	—	1.67	
Plastering Materials						
Cement plaster, sand aggregate ...	116	5.0	—	0.20	—	0.20
Sand aggregate ... 0.375 in.	—	—	13.33	—	0.08	0.20
Sand aggregate ... 0.75 in.	—	—	6.66	—	0.15	0.20
Gypsum plaster:						
Lightweight aggregate ... 0.5 in.	45	—	3.12	—	0.32	
Lightweight aggregate ... 0.625 in.	45	—	2.67	—	0.39	
Lightweight agg. on metal lath ... 0.75 in.	—	—	2.13	—	0.47	
Perlite aggregate ...	45	1.5	—	0.67	—	0.32
Sand aggregate ...	105	5.6	—	0.18	—	0.20
Sand aggregate ... 0.5 in.	105	—	11.10	—	0.09	
Sand aggregate ... 0.625 in.	105	—	9.10	—	0.11	
Sand aggregate on metal lath ... 0.75 in.	—	—	7.70	—	0.13	
Vermiculite aggregate ...	45	1.7	—	0.59	—	
Roofing						
Asbestos-cement shingles ... 120	—	4.76	—	0.21	0.24	
Asphalt roll roofing ...	70	—	6.50	—	0.15	0.36
Asphalt shingles ...	70	—	2.27	—	0.44	0.30
Built-up roofing ... 0.375 in.	70	—	3.00	—	0.33	0.35
Slate ... 0.5 in.	—	—	20.00	—	0.05	0.30
Wood shingles, plain and plastic film faced ...	—	—	1.06	—	0.94	0.31

Description	Density (lb/ft³)	Conductivity (k)	Conductance (C)	Resistance[1] (R) Per inch thickness (1/k)		Specific Heat, Btu/(lb)(deg F)
Siding Materials (on Flat Surface)						
Shingles						
Asbestos-cement	120	—	4.75	—	0.21	
Wood, 16 in., 7.5 exposure	—	—	1.15	—	0.87	0.31
Wood, double, 16-in., 12-in. exposure	—	—	0.84	—	1.19	0.28
Wood, plus insul. backer board, 0.3125 in.	—	—	0.71	—	1.40	0.31
Siding						
Asbestos-cement, 0.25 in., lapped	—	—	4.76	—	0.21	0.24
Asphalt roll siding	—	—	6.50	—	0.15	0.35
Asphalt insulating siding (0.5 in. bed.)	—	—	0.69	—	1.46	0.35
Wood, drop, 1 x 8 in.	—	—	1.27	—	0.79	0.28
Wood, bevel, 0.5 x 8 in., lapped	—	—	1.23	—	0.81	0.28
Wood, bevel, 0.75 x 10 in., lapped	—	—	0.95	—	1.05	0.28
Wood, plywood, 0.375 in., lapped	—	—	1.59	—	0.59	0.29
Wood, medium density siding, 0.4375 in.	40	1.49	—	0.67		0.28
Aluminum or Steel[11], over sheathing						
Hollow-backed	—	—	1.61	—	0.61	0.29
Insulating-board backed nominal 0.375 in.	—	—	0.55	—	1.82	0.32
Insulating-board backed nominal 0.375 in., foil backed			0.34		2.96	
Architectural glass	—	—	10.00	—	0.10	0.20
Woods						
Maple, oak, and similar hardwoods	45	1.10	—	0.91	—	0.30
Fir, pine, and similar softwoods	32	0.80	—	1.25	—	0.33
0.75 in.	32	—	1.06	—	0.94	0.33
1.5 in.		—	0.53	—	1.89	
2.5 in.		—	0.32	—	3.12	
3.5 in.		—	0.23	—	4.35	

NOTES:

1. Resistance values are the reciprocals of C before rounding off C to two decimal places.
2. Conductivity varies with fiber diameter. Insulation is produced by different densities, therefore, there is a wide variation in thickness for the same R-value among manufacturers. No effort should be made to relate any specific R-value to any specific thickness. Commercial thicknesses generally available ran from 2 to 8.5.
3. Does not include paper backing and facing, if any.
4. Values are for aged board stock.
5. Insulating values of acoustical tile vary, depending on density of the board and on type, size and depth of perforations.
6. The U.S. Department of Commerce, Simplified Practice Recommendation for Thermal Conductance Factors for Preformed Above-Deck Roof Insulation, No. R 257-55, recognizes the specifications of roof insulation on the basis of the C-values shown. Roof insulation is made in thicknesses to meet the values.
7. Face brick and common brick do not always have these specific densities. When density is different from that shown, there will be a change in thermal conductivity.
8. Data on rectangular core concrete blocks differ from the above data on oval core blocks, due to core configuration, different mean temperatures, and possibly differences in unit weights. Weight data of the oval core blocks tested are not available.
9. Weights of units approximately 7.625 in. high and 15.75 in. long. These weights are given as a means of describing the blocks tested, but conductance values are all for 1 ft² of area.
10. Vermiculite, perlite, or mineral wool insulation. Where insulation is used, vapor barriers or other precautions must be considered to keep insulation dry.
11. Values for metal siding applied over flat surfaces vary widely, depending on amount of ventilation air space beneath the siding; whether air space is reflective or nonreflective;and on thickness, type, and application of insulating backing-board used. Values given are averages for use as design guides, and were obtained from several guarded hotbox tests (ASTM C236) or calibrated hotbox (BSS 77) on hollow backed types and types made using backing-boards of wood fiber, foamed plastic, and glass fiber. Departures of ±50% or more from the values given may occur.

2. Thermal Conductivity (k) of Industrial Insulation for Mean Temperatures Indicated

(Expressed in Btu/hr-sq. ft.-°F-in.)

Form / Material Composition	Accepted Max Temp for Use, F	Typical Density (lb/ft³)	-100	-75	-50	-25	0	25	50	75	100	200	300	500	700	900
Blankets & Felts																
Mineral Fiber																
(Rock, slag or glass) Blanket, metal reinforced	1200	6-12									0.26	0.32	0.39	0.54		
	1000	2.5-6									0.24	0.31	0.40	0.61		
Mineral fiber, glass Blanket, flexible, fine-fiber	350	0.65				0.25	0.26	0.28	0.30	0.33	0.36	0.53				
Organic bonded		0.75				0.24	0.25	0.27	0.29	0.32	0.34	0.48				
		1.0				0.23	0.24	0.25	0.27	0.29	0.32	0.43				
		1.5				0.21	0.22	0.23	0.25	0.27	0.28	0.37				
		2.0				0.20	0.21	0.22	0.23	0.25	0.26	0.33				
		3.0				0.19	0.20	0.21	0.22	0.23	0.24	0.31				
Blanket, flexible, textile-fiber organic bonded	350	0.65				0.27	0.28	0.29	0.30	0.31	0.32	0.50	0.68			
		0.75				0.26	0.27	0.28	0.29	0.31	0.32	0.48	0.66			
		1.0				0.24	0.25	0.26	0.27	0.29	0.31	0.45	0.60			
		1.5				0.22	0.23	0.24	0.25	0.27	0.29	0.39	0.51			
		3.0				0.20	0.21	0.22	0.23	0.24	0.25	0.32	0.41			
Felt, semirigid organic bonded	400	3-8						0.24	0.25	0.26	0.27	0.35	0.44			
Laminated & felted	850	3	0.16	0.17	0.18	0.19	0.20	0.21	0.22	0.23	0.24	0.35	0.55			
Without binder	1200	7.5											0.35	0.45	0.60	
Vegetable & Animal Fiber																
Hair felt or hair felt plus jute	180	10						0.26	0.28	0.29	0.30					
Blocks, Boards & Pipe Insulation																
Asbestos																
Laminated asbestos paper	700	30									0.40	0.45	0.50	0.60		
Corrugated & laminated asbestos Paper																
4-ply	300	11-13								0.54	0.57	0.68				
6-ply	300	15-17								0.49	0.51	0.59				
8-ply	300	18-20								0.47	0.49	0.57				
Molded Amosite & Binder	1500	15-18									0.32	0.37	0.42	0.52	0.62	0.72
85% Magnesia	600	11-12									0.35	0.38	0.42			
Calcium Silicate	1200	11-13									0.38	0.41	0.44	0.52	0.62	0.72
	1800	12-15												0.63	0.74	0.95
Cellular Glass	800	9			0.32	0.33	0.35	0.36	0.38	0.40	0.42	0.48	0.56			
Diatomaceous Silica	1600	21-22												0.64	0.68	0.72
	1900	23-25												0.70	0.75	0.80
Mineral Fiber																
Glass, Organic bonded, block & boards	400	3-10	0.16	0.17	0.18	0.19	0.20	0.22	0.24	0.25	0.26	0.33	0.40			

Form / Material Composition	Accepted Max Temp for Use, F[1]	Typical Density (lb/ft³)	Typical Conductivity (k) at Mean Temp F. -100	-75	-50	-25	0	25	50	75	100	200	300	500	700	900
Mineral Fiber (continued)																
Nonpunking binder	1000	3-10									0.26	0.31	0.38	0.52		
Pipe insulation, slag or glass	350	3-4					0.20	0.21	0.22	0.23	0.24	0.29				
	500	3-10					0.20	0.22	0.24	0.25	0.26	0.33	0.40			
Inorganic bonded-block	1000	10-15									0.33	0.38	0.45	0.55		
	1800	15-24									0.32	0.37	0.42	0.52	0.62	0.74
Pipe insulation, slag or glass	1000	10-15									0.33	0.38	0.45	0.55		
Resin binder		15			0.23	0.24	0.25	0.26	0.28	0.29						
Rigid Polystyrene																
Extruded, Refrigerant 12 exp.	170	3.5	0.16	0.16	0.15	0.16	0.16	0.17	0.18	0.19	0.20					
Extruded, Refrigerant 12 exp.	170	2.2	0.16	0.16	0.17	0.16	0.17	0.18	0.19	0.20						
Extruded	170	1.8	0.17	0.18	0.19	0.20	0.21	0.23	0.24	0.25	0.27					
Molded beads	170	1	0.18	0.20	0.21	0.23	0.24	0.25	0.26	0.28						
Polyurethane[2]																
Refrigerant 12 exp.	210	1.5-2.5	0.16	0.17	0.18	0.18	0.18	0.17	0.16	0.16	0.17					
Rubber, Rigid Foamed	150	4.5						0.20	0.21	0.22	0.23					
Vegetable & Animal Fiber																
Wool felt (pipe insulation)	180	20						0.28	0.30	0.31	0.33					
Insulating Cements																
Mineral Fibers																
(Rock, slag, or glass)																
With colloidal clay binder	1800	24-30									0.49	0.55	0.61	0.73	0.85	
With hydraulic setting binder	1200	30-40									0.75	0.80	0.85	0.95		
Loose Fill																
Cellulose insulation (milled pulverized paper or wood pulp)		2.5-3							0.26	0.27	0.29					
Mineral fiber, slag, rock or glass		2-5			0.19	0.21	0.23	0.25	0.26	0.28	0.31					
Perlite (expanded)		5-8	0.25	0.27	0.29	0.30	0.32	0.34	0.35	0.37	0.39					
Silica aerogel		7.6			0.13	0.14	0.15	0.15	0.16	0.17	0.18					
Vermiculite (expanded)		7-8.2			0.39	0.40	0.42	0.44	0.45	0.47	0.49					
		4-6			0.34	0.35	0.38	0.40	0.42	0.44	0.46					

NOTES: 1. These temperatures are generally accepted as maximum. When operating temperature approaches these limits follow the manufacturer's recommendations.

2. Values are for aged board stock. Note: Some polyurethane foams are formed by means which produce a stable product (with respect to k), but most are blown with refrigerant and will change with time.

3. U Values of Solid Wood Doors

	Btu per (hr-ft²-F)			
	Winter			Summer
	No Storm Door	Storm Door[2]		No Storm Door
Thickness[1]		Wood	Metal	
1-in	0.64	0.30	0.39	0.61
1.25-in.	0.55	0.28	0.34	0.53
1.5-in.	0.49	0.27	0.33	0.47
2-in.	0.43	0.24	0.29	0.42

NOTES: 1. Nominal thickness.
2. Values for wood storm doors are for approximately 50% glass; for metal storm door values apply for any percent of glass.

4. U Values of Windows, Skylights and Light-Transmitting Partitions

(These values are for heat transfer from air to air in BTU/hr-sq. ft-°F.)

PART A—Vertical Panels (Exterior Windows, Sliding Patio Doors, and Partitions)—Flat Glass, Glass Block and Plastic Sheet

	Exterior[1]		
Description	Winter	Summer	Interior
Flat Glass[2]			
Single glass	1.10	1.04	0.73
Insulating glass—double[3]			
0.1875-in. air space[4]	0.62	0.65	0.51
0.25-in. air space[4]	0.58	0.61	0.49
0.5-in. air space[5]	0.49	0.56	0.46
0.5-in. air space, low emittance coating[6]			
e = 0.20	0.32	0.38	0.32
e = 0.40	0.38	0.45	0.38
e = 0.60	0.43	0.51	0.42
Insulating glass—triple[3]			
0.25-in. air spaces[4]	0.39	0.44	0.38
0.5-in. air spaces[7]	0.31	0.39	0.30
Storm windows			
1-in. to 4-in. air space[4]	0.50	0.50	0.44
Plastic Sheet			
Single glazed			
0.125-in. thick	1.06	0.98	—
0.25-in. thick	0.96	0.89	—
0.5-in. thick	0.81	0.76	—
Insulating unit—double[3]			
0.25-in. air space[4]	0.55	0.56	—
0.5-in. air space[4]	0.43	0.45	—
Glass Block[8]			
6 × 6 × 4 in. thick	0.60	0.57	0.46
8 × 8 × 4 in. thick	0.56	0.54	0.44
—with cavity divider	0.48	0.46	0.38
12 × 12 × 4 in. thick	0.52	0.50	0.41
—with cavity divider	0.44	0.42	0.36
12 × 12 × 2 in. thick	0.60	0.57	0.46

PART B—Horizontal Panels (Skylights)—Flat Glass, Glass Block, and Plastic Domes

	Exterior[1]		
Description	Winter[4]	Summer[10]	Interior[4]
Flat Glass[2]			
Single glass	1.23	0.83	0.96

PART B—Horizontal Panels (Skylights)—Flat Glass, Glass Block, and Plastic Domes

Description	Exterior[1]		Interior[1]
	Winter[9]	Summer[10]	
Flat Glass[2]			
	1.23	0.83	0.96

Description	Exterior[1]		Interior[1]
	Winter[9]	Summer[10]	
Insulating glass—double[3]			
0.1875-in. air space[4]	0.70	0.57	0.62
0.25-in. air space[4]	0.65	0.54	0.59
0.5-in. air space[5]	0.59	0.49	0.56
0.5-in. air space, low emittance coating[6]			
e = 0.20	0.48	0.36	0.39
e = 0.40	0.52	0.42	0.45
e = 0.60	0.56	0.46	0.50
Glass Block[8]			
11 x 11 x 3 in. thick with cavity divider	0.53	0.35	0.44
12 x 12 x 4 in. thick with cavity divider	0.51	0.34	0.42
Plastic Domes[11]			
Single-walled	1.15	0.80	—
Double-walled	0.70	0.46	—

PART C—Adjustment Factors for Various Window and Sliding Patio Door Types (Multiply U Values in Parts A and B by These Factors)

Description	Single Glass	Double or Triple Glass	Storm Windows
Windows			
All glass[12]	1.00	1.00	1.00
Wood sash—80% glass	0.90	0.95	0.90
Wood sash—60% glass	0.80	0.85	0.80
Metal sash—80% glass	1.00	1.20[13]	1.20
Sliding Patio Doors			
Wood frame	0.95	1.00	—
Metal frame	1.00	1.10[13]	—

NOTE:
1. See Part C for adjustment for various window and sliding patio door types.
2. Emittance of uncooled glass surface = 0.84
3. Double and triple refer to the number of lights of glass.
4. 0.125-in. glass.
5. 0.25-in. glass.
6. Coating on either glass surface facing air space, all other glass surfaces uncoated.
7. Window design: 0.25-in. glass—0.125-in. glass—0.25-in. glass.
8. Dimensions are nominal.
9. For heat flow up.
10. For heat flow down.
11. Based on area of opening, not total surface area.
12. Refers to windows with negligible opaque area.
13. Values will be less than these when metal sash and frame incorporate thermal breaks. In some thermal break designs, U values will be equal to or less than those for the glass. Window manufacturers should be consulted for specific data.

5. Resistance (R) Values of Air Surfaces

Position of Surface	Direction of Heat Flow	Type of Surface: Nonreflective Materials Resistance (R)	Reflective Aluminum Coated Paper Resistance (R)	Highly Reflective Foil Resistance (R)
Still Air				
Horizontal	Upward	0.61	1.10	1.32
45° slope	Upward	0.62	1.14	1.37
Vertical	Horizontal	0.68	1.35	1.70
45° slope	Down	0.76	1.67	2.22
Horizontal	Down	0.92	2.70	4.55
Moving Air				
(any position) 15 mph wind	Any	0.17 (winter)	—	—
7½ mph wind	Any	0.25 (summer)	—	—

6. Resistance (R) Values of Air Spaces

	Position of Air Space and Thickness (in.)	Direction of Heat Flow	Season	Type of Surfaces on Opposite Sides: Both Surfaces Nonreflective Materials Resistance (R)	Aluminum Coated Paper/Non-Reflective Material Resistance (R)	Foil/Non-Reflective Material Resistance (R)
Horizontal	¾	Up	W	0.87	1.71	2.23
	¾		S	0.76	1.63	2.26
	4		W	0.94	1.99	2.73
	4		S	0.80	1.87	2.75
45° slope	¾	Up	W	0.94	2.02	2.78
	¾		S	0.81	1.90	2.81
	4		W	0.96	2.13	3.00
	4		S	0.82	1.98	3.00
Vertical	¾	Horizontal	W	1.01	2.36	3.48
	¾		S	0.84	2.10	3.28
	4		W	1.01	2.34	3.45
	4		S	0.91	2.16	3.44
45° slope	¾	Down	W	1.02	2.40	3.57
	¾		S	0.84	2.09	3.24
	4		W	1.08	2.75	4.41
	4		S	0.90	2.50	4.36
Horizontal	¾	Down	W	1.02	2.39	3.55
	1½		W	1.14	3.21	5.74
	4		W	1.23	4.02	8.94
	¾		S	0.84	2.08	3.25
	1½		S	0.93	2.76	5.24
	4		S	0.99	3.38	8.03

APPENDIX C. Performance Predictions

Residential Energy Costs

A residence's actual energy costs will be lower than the figure you arrived at on the heat loss worksheet. Two factors reducing actual costs are internal gains and passive solar input. The following procedure should be followed.

1. Adjust for internal gains.

No. of family members	Intergain (BTU/Day)
2	45,000
4	60,000
6	80,000
8	100,000

a. Internal heat gain ÷ BLC = °F below 65°F that will be supplied by internal gain. Subtract this number from 65°F to determine new DD base.
Example: 60,000 ÷ 6037 = 9.94°F
65°F − 9.94°F = 55.06°F

b. Refer to Appendix A for appropriate station, and determine new seasonal DD based on the new temperature.
Example: 55.06 is very close to DD55, yielding an annual adjusted DD of 6607 in Fargo.

A	B	C	D	E	F	G
Month	Daily Solar Insolation	Efficiency Factor[1]	Total Solar[2]	Monthly DD	B.L.C.	Auxiliary Energy[3]
Oct.	1324	.5	820,880	260	6037	748,740
Nov.	902	.5	541,200	792	6037	4,240,104
Dec.	752	.5	466,240	1302	6037	7,393,934
Jan.	873	.5	541,260	1522	6037	8,647,054
Feb.	1184	.5	663,040	1230	6037	6,822,840
Mar.	1380	.5	855,600	956	6037	4,909,735
April	1312	.5	787,200	384	6037	1,531,008

Total Auxiliary 34,293,415

Auxiliary Cost = 34,293,415 × $\frac{.035}{3413}$

Auxiliary Cost = $351.68

[1]Efficiency factors – Direct Gain = .5
Greenhouse = .4
Trombe Wall = .30

[2]Total Solar = B × C × ft^2 south glass × days in month

[3]Auxiliary Energy = E × F − D

Note: There are 40 ft^2 of South facing glass in this example.

RESOURCE LIST

BOOKS

General Energy Concerns

A Pattern Language Christopher Alexander, et al., Oxford University Press, 1977.

The Handbook of Moving Air Harrison A. Dunlavy, American Ventilation Association, 1976.

Energy and Form Ralph L. Knowles, The MIT Press, 1978.

Energy Primer Richard Merrill, Delta Books, 1978.

County Energy Plan Guidebook Alan Okagaki et al., Institute for Ecological Policies, 1979.

Energy-Efficient Community Planning James Ridgeway, The J.G. Press, 1976.

Explaining Energy Lee Schipper, et al., NTIS U.S. Department of Commerce, 1976.

Energy Future Robert Stobaugh, et al., Random House, 1979.

Residential and Solar

The Solar Home Book Bruce Anderson, Cheshire Books, 1976.

Sunset Homeowner's Guide to Solar Heating and Cooling Holly Lyman Antolini, Lane Publishing Co., 1978.

The Well-Tempered House Robert Argue, Renewable Energy in Canada, 1980.

The First Passive Solar Catalog David Bainbridge, Passive Solar Institute, 1978.

The Second Passive Solar Catalog David Bainbridge, Passive Solar Institute, 1980.

Passive Solar Design Handbook, Vol. II J. Douglas Balcomb, et al., NTIS U.S. Department of Commerce, 1980.

The Complete Book of Insulating Larry Gay, The Stephen Green Press, 1980.

The Passive Solar Energy Book Ed Mazria, Rodale Press, 1979.

Residential Water Conservation Murray Milne, NTIS U.S. Department of Commerce, 1975.

Residential Energy Conservation Office of Technology Assessment, Allanheld, Osmun and Co. Publishers, Inc., 1980.

New Inventions in Low-Cost Solar Heating William A. Shurcliff, Brick House Publishing Co., 1979.

Solar Heated Homes of North America William A. Shurcliff, Brick House Publishing Co., 1978.

Superinsulated Houses and Double-Envelope Houses William A. Shurcliff, William A. Shurcliff, 1980.

A Design and Construction Handbook for Energy Saving Houses Alex Wade, Rodale Press, 1980.

30 Energy Efficient Houses. . .You Can Build Alex Wade, et al., Rodale Press, 1977.

From the Walls In Charles Wing, Atlantic Monthly Press, 1979.

Natural Solar Architecture: A Passive Primer David Wright, Van Nostrand Reinhold Co., 1978.

Greenhouses

The Complete Greenhouse Book Peter Clegg, et al., Garden Way, 1978.

The Survival Greenhouse James Dekoorne, Peace Press, 1978.

The Food and Heat Producing Solar Greenhouse Rich Fisher, et al., John Muir Productions, 1980.

The Solar Greenhouse Book James McCullagh, Rodale Press, 1978.

Window Insulation

Moveable Insulation William K. Langdon, Rodale Press, 1980.

Thermal Shutters and Shades William A. Shurcliff, Brick House Publishing Co., 1980.

Underground and Earth Sheltered Construction

The Use of Earth Covered Buildings Conference Proceedings, U.S. Government Printing Office, 1976.

The Underground House Book Stu Campbell, Garden Way Publishing Co., 1980.

Earth Sheltered Housing Design The Underground Space Center at the University of Minnesota, Van Nostrand Reinhold Co., 1978.

Underground Designs Malcolm Wells, Malcom Wells, 1977.

Commercial

ASHRAE Handbook of Fundamentals ASHRAE staff, ASHRAE Publications Department, 1981.

American Building James Marston Fitch, Houghton Mifflin, 1972.

Applications of Solar Energy for Heating and Cooling of Buildings Richard C. Jordan, et al., ASHRAE Publications Department, 1977.

Architects and Engineers Guide to Energy Conservation Existing Buildings NTIS U.S. Department of Commerce, 1980.

Energy Efficient Buildings Walter F. Wagner, Jr., McGraw-Hill Inc., 1980.

Technical Note 14: Details and Engineering Analysis of Illinois Lo-Cal House Illinois Small Homes Council.

Other Sources Of Information And Active Organizations

American Section, I.S.E.S., A.T.U. P.O. Box 1416, Killeen, TX 76541, $25/yr.

National Center for Appropriate Technology, P.O. Box 3838, Butte, MT 59701.

Small Homes Council, Research Council, University of Illinois at Urbana, Champaign, IL 61801.

Energy Research Development Group, Department of Mechanical Engineering, University of Saskatchewan, Saskatoon, Saskatchewan, S7N OWO.

Family Housing Handbook by Midwest Plan Service. Available at County Extension Offices.

Residential Air-To-Air Heat Exchangers (Manufacturers and Distributors)

Besant, R.W., R.S. Dumont and D. Van Ee; An air to air heat exchanger for residences. University of Saskatchewan, Extension Division, Saskatoon, Saskatchewan, Canada S7N 0W0

Des Champs Labs Inc., P.O. Box 348, East Hanover, NJ 07936

Q-Dot Corp., 151 Regal Row, Dallas, TX 75247

Van EE, Heat Recovery Ventilation System
Canada - Head Office/Manufacturing
CES - Conservation Energy Systems, Inc.
P.O. Box 8280, 800 Spa Dina Cres., East Saskatoon, Sask. S7K 6C6
USA - Head Office/Distribution
Sola Tech, Inc. Environmental Energy Systems
1325 East 79 Street, Minneapolis, MN 55420

The Air Changer Co., 34 King St. E., Toronto, Ont. M5A 1K8 CANADA

Aldes Riehs, Box 157, Glenfield Rd., Sewickley, PA 15143

Berner Int. Corp., 12 Sixth Rd., Woburn, MA 01801

Blackhawk Industries, Inc., 607 Park St., Regina, Saskatchewan S4N 5NI

Ener Corp., Management Ltd., 2 Donald St., Winnipeg, Man. R3L 0K5 CANADA

Mitsubishi Electric, Sales America, 3030 E. Victoria St., Compton, CA 90221

The Air Changer Co., Ltd., 334 King St. E., Toronto, Ont. CANADA M5A 1K8

Heat X Changer, EER Products, Inc., 3526 East 28 Street, Minneapolis, MN 55406

Xchange Air, Solartronics, Inc., P.O. Box 534, Fargo, ND 58107

Van EE, Solatech, Inc., 1325 East 79 Street, Minneapolis, MN 55420

Barn Ventilation Heat Exchangers

Aerovent Fan & Equipment Co., 929 Terminal Road, Lansing, MI 48906 (517) 323-2930

JLCO, Inc., Box D, Dassel, MN 55325 (612) 275-3373

Del Air Systems Ltd., P.O. Box 2500, Humboldt, Sask. S0K 2A0

HyTemp Manufacturing, 3035 Saratoga St., Omaha, NE 68111 800-228-7256

Blackhawk Industries, Inc., 607 Park St., Regina, Sask. (306) 924-1551

Agri-Aide, Box 241, Glenwood, MN 56334 (612) 634-5188

Ray Dot, 145 Jackson Avenue, Cokato, MN 55321 (612) 286-2103

Vet-Agri, Inc., 1445 South Third Street
Niles, MI 49120 (616) 684-4348

Exterior Insulation Systems

Dryvit Systems, Inc., 420 Lincoln Ave., Warwick, RI 02888 (401) 463-7150.

Compo Industries (SETTEF), Chemical Specialities Group, 125 Roberts Rd., Waltham, MA 02154, (617) 899-3000.

Insul/Crete Co., Inc., 4311 Triangle St., McFarland, WI 53559, (608) 838-4541.

Interior Bonded Insulation Systems

R Max Inc., 13524 Welch Rd., Dallas, TX 75240, (214) 387-4500.

Panel ERA, 3447 S. Main St., Salt Lake City, UT 84115, (801) 972-3994.

SOME SOURCES OF ENERGY EFFICIENT HOUSE PLANS

1. Extension Agricultural Engineering, NDSU, Fargo, North Dakota 58105. Plans provided from the USDA show general construction, floor plan, etc. Energy conservation house plans include house construction research. MWPS-16. "Family Housing Handbook" is being revised and 1971 edition is available.

2. Minnesota State Documents, 117 University Ave., St. Paul, Minnesota 55155 (612/297-3000). Have four special plans available ($25.00 per set) on superinsulated homes including Northern States Power "Northstar" home. A description leaflet is available on these plans. A publication entitled "Prototype Ventilation System for Superinsulated Houses Using Forced Air Duct System" is available at $4.00 per copy.

3. Home Planners, Inc., 23761 Research Drive, Farmington Hills, Michigan (1-800/521-6797) advertises several hundred houseplans adaptable to energy conservation construction. Plan cost begins at $95.00 per set. Description leaflets are available.

4. National Center for Appropriate Technology, Publication Division, Box 3838, Butte, Montana 59702 (406/494-4577). Have two plans for construction of superinsulated houses for cold climate. $75.00 per plan for large sheets, $50.00 per plan for small sheets. A description brochure is available.

5. Iowa Energy Policy Council, Lucas State Office Building, Sixth Floor, Des Moines, IA 50319.

6. Department of Energy and Natural Resources, Energy Information Clearing House, 325 West Adams Street, Springfield, Illinois 62706 (217/785-2800).

7. Superinsulation Designs, Corbett/Hanson and Associates, P.O. Box 3706, Butte, Montana 59702 (406/494-2592).

8. Agricultural Engineering Section, Extension Service, Saskatchewan Agriculture, 3085 Albert Street, Regina Saskatchewan, Canada 545-OB1 (306/787-6584). Two publications available, "Guidelines for Planning the Rural Home" and "Floor Plans for Rural Living," at no charge.

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